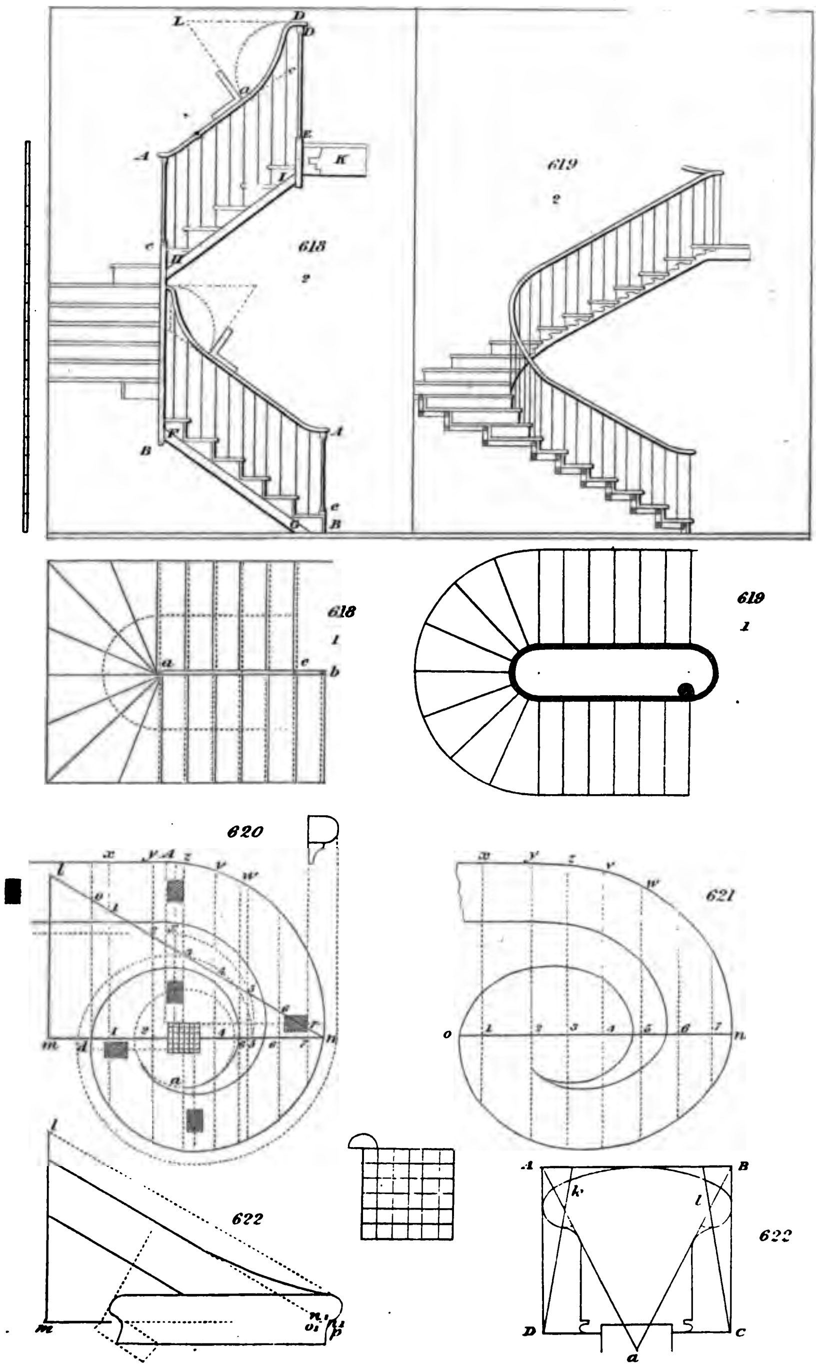
BUILDING

Plate 87._*From 618 to 622*_Page 598.



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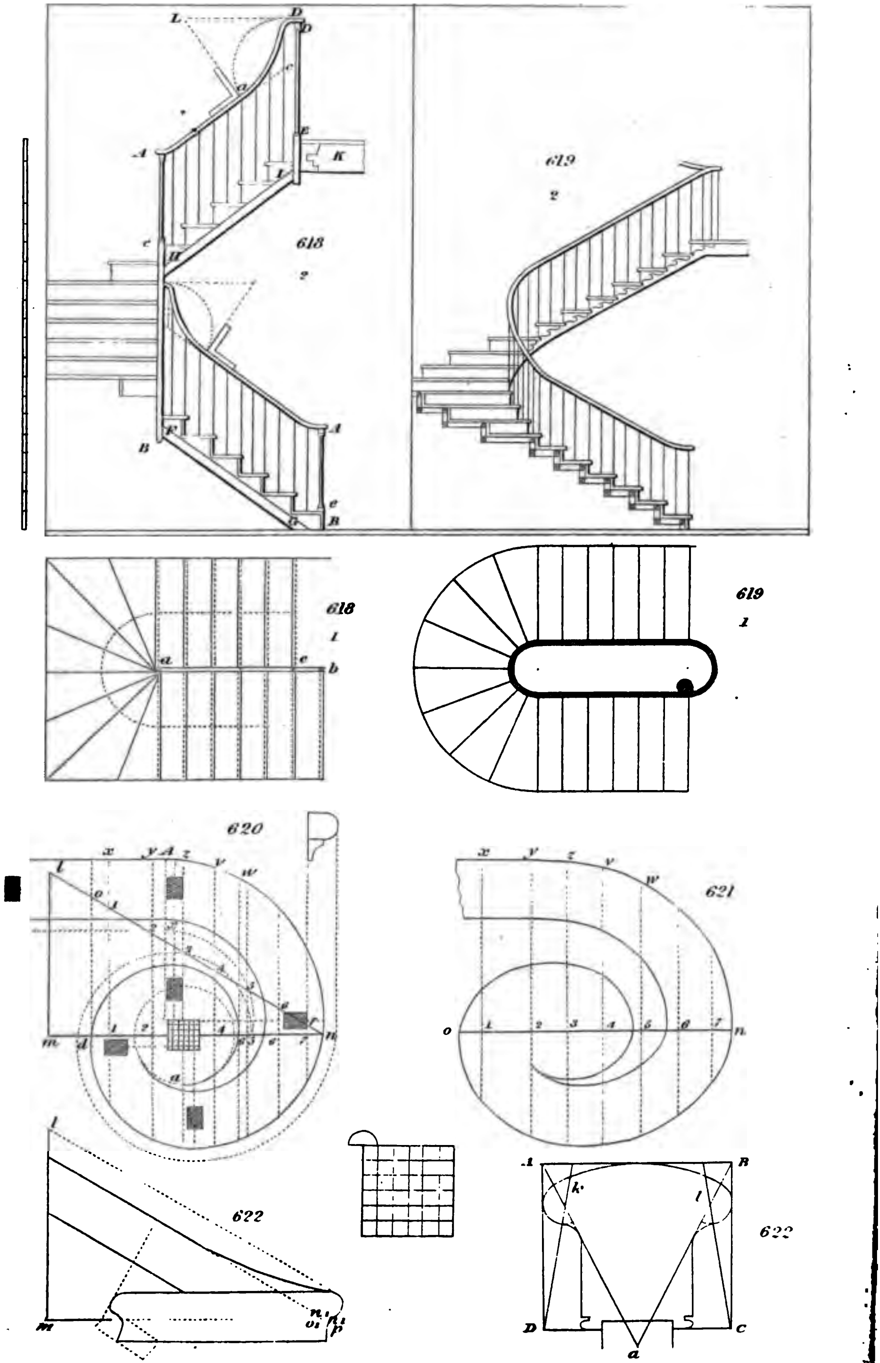

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THE BUILDER'S PRACTICAL GUIDE:

CONTAINING

A COMPLETE EXPLANATION OF

THE PRINCIPLES OF SCIENCE,

AS APPLIED TO

EVERY BRANCH OF BUILDING:

Comprising an Entire Course of Instruction for

MASONS,	SLATERS,
BRICKLAYERS,	PLUMBERS,
CARPENTERS,	GLAZIERS,
JOINERS,	AND
PLASTERERS,	PAINTERS;

INCLUDING THE CUSTOMARY METHODS OF ESTIMATING, MEASURING, AND CHARGING; WITH TABLES.

TO WHICH IS ADDED

AN APPENDIX,

CONTAINING

AN EASY AND COMPLETE INTRODUCTION TO THE SCIENTIFIC PRINCIPLES

OF

GEOMETRY AND MENSURATION,

SO FAR AS THOSE SCIENCES ARE APPLICABLE

TO THE

USEFUL ARTS.

BY JOHN NICHOLSON, ESQ.
CIVIL ENGINEER.

ILLUSTRATED BY FIFTEEN ENGRAVINGS.

LONDON:
PRINTED FOR SHERWOOD, GILBERT, AND PIPER,
PATERNOSTER-ROW.

1830.

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For further Directions to the Binder, see the end of the Work.

TO THE READER.

THE well-merited celebrity and eminent character of NICHOLSON'S OPERATIVE MECHANIC AND BRITISH MACHINIST, are so fully established, that no commendation need be bestowed on a production which deservedly ranks as the first of all works hitherto published on the Literature of the Useful Arts: but as many divisions of that work, however interesting they may be to the general student, or important and useful to the intelligent Operative in their particular departments, may nevertheless possess only a secondary interest to persons not immediately engaged in those peculiar pursuits, the Proprietor of that work has printed the Section on BUILDING separately from the rest of the work, in order to furnish an invaluable manual to those engaged in the various occupations of that division of practical science, at a very moderate expence.

As a clear, concise and easy INTRODUCTION TO THE PRINCIPLES OF GEOMETRY AND MENSURATION is highly desirable to all persons engaged in Building, a few pages of APPENDIX are added, with the requisite explanatory Engravings, in order to furnish an interesting source of valuable instruction to the scientific mechanic, and to explain with great ease many useful problems, which will facilitate the comprehending a great number of important calculations and operations, which a long course of practical experience, unassisted by such help, might in vain endeavour to effect.

BUILDING.

UNDER this general term, which implies the construction of an edifice according to the rules laid down by the different artificers employed, we purpose to treat of the respective business of the Mason, Bricklayer, Carpenter, Joiner, Plasterer, Plumber, Painter, and Glazier; previous to which it will be necessary to consider the sinking of the foundation, the due mixture of the ingredients which compose the mortar, and the art of making bricks; upon the whole of which materially depends the stability of an edifice.

As firmness of foundation is indispensable, wherever it is intended to erect a building, the earth must be pierced by an iron bar, or struck with a rammer, and if found to shake, must be bored with a well-sinker's implement, in order to ascertain whether the shake be local or general. If the soil is in general good, the loose and soft parts, if not very deep, must be excavated until the labourers arrive at a solid bed capable of sustaining the pier or piers to be built. If not very loose, it may be made good by ramming into it very large stones, packed close together, and of a breadth proportionate to the intended weight of the building; but where very bad, it must be piled and planked.

In places where the soil is loose to any great depth, and over which it is intended to place apertures, such as doors, windows, &c. while the parts on which the piers are to stand are firm, the best plan is to turn an inverted arch under each intended aperture, as then the piers in sinking will carry with them the inverted arch, and by compressing the ground compel it to act against the under sides of the arch, which, if closely jointed, so far from yielding, will, with the abutting piers, operate as one solid body; but, on the contrary, if this expedient of the inverted arch is not adopted, the part of the wall under the aperture, being of less height, and consequently of less weight than the piers, will give way to the resistance of the soil acting on its base, and not only injure the brick-work between the apertures, but fracture the window-heads and cills.

In constructing so essential a part as the arch, great attention must be paid to its curvature, and we strongly recommend the parabolic curve to be adopted, as the most effectual for the purpose; but if, in consequence of its depth, this cannot conveniently be introduced, the arch should never be made less than a semi-circle. The bed of the piers should be as uniform as possible, for, though the bottom of the trench be very firm, it will in some degree yield to the great weight that is upon it, and if the soil be softer in one part than in another, that part which is the softest, of course will yield more to the pressure, and cause a fracture.

If the solid parts of the trench happen to be under the intended apertures, and the softer parts where piers are wanted, the reverse of the above practice must be resorted to; that is, the piers must be built on the firm parts, and have an arch that is not inverted between them. In performing this, attention must be paid to ascertain whether the pier will cover the arch; for if the middle of the pier rest over the middle of the summit of the arch, the narrower the pier is, the greater should be the curvature of the arch at its apex. When suspended arches are used, the intrados ought to be kept clear of the ground, that the arch may have its due effect.

When the ground is in such a state as to require the foundation merely to be rammed, the stones are hammer-dressed, so as to be as little taper as possible, then laid of a breadth proportioned to the weight that is to be rested upon them, and afterwards well rammed together. In general, the lower bed of stones may be allowed to project about a foot from the face of the wall on each side, and on this bed another course may be laid to bring the bed of stones on a level with the top of the trench. The breadth of this upper bed of stones should be four inches less than the lower one; that is, projecting about eight inches on either side of the wall. In all kinds of walling, each joint of every course must fall as nearly as possible in the centre, between two joints of the course immediately below it; for in all the various methods of laying stones or bricks, the principal aim is to procure the greatest lap on each other.

MORTAR.

In making mortar, particular attention must be paid to the quality of the sand, and if it contain any propor-

tion of clay or mud, or is brought from the sea-shore and contains saline particles, it must be washed in a stream of clear water till it be divested of its impurities. The necessity of the first has been clearly proved by Mr. Smeaton, who, in the course of a long and meritorious attention to his profession of an engineer, has found, that when mortar, though otherwise of the best quality, is mixed with a small proportion of unburnt clay, it never acquires that hardness which, without it, it would have attained; and, with respect to the second, it is evident, that so long as the sand contains saline particles it cannot become hard and dry. The sharper and coarser the sand is the better for the mortar, and the less the quantity of lime to be used; and sand being the cheapest of the ingredients which compose the mortar, it is more profitable to the maker. The exact proportions of lime and sand are still undetermined; but in general no more lime is required than is just sufficient to surround the particles of the sand, or sufficient to preserve the necessary degree of plasticity.

Mortar, in which sand forms the greater portion requires less water in its preparation, and consequently is sooner set. It is also harder and less liable to shrink in drying, because the lime, while drying, has a greater tendency to shrink than sand, which retains its original magnitude. The general proportions given by the London builders is 1½ cwt., or 37 bushels, of lime to 2½ loads of sand; but if proper measures be taken to procure the best burnt lime and the best sand, and in tempering the materials, a greater portion of sand may be used. There is scarcely any mortar that has the lime well calcined, and the composition well beaten, but that will be found to-require two parts of sand to one part of unslacked lime; and it is worthy of observation, that the more the mortar is beaten the less proportion of lime suffices.

Many experiments have been made with a view to obtain the most useful proportion of the ingredients, and among the rest Dr. Higgins has given the following:—

Lime newly slacked one part,
Fine sand three parts; and
Coarse sand four parts.

He also found that one-fourth of the lime of bone-ashes greatly improved the mortar, by giving it tenacity, and rendering it less liable to crack in the drying.

It is best to slack the lime in small quantities as required

for use, about a bushel at a time, in order to secure to the mortar such of its qualities as would evaporate were it allowed to remain slacked for a length of time. But if the mortar be slacked for any considerable time previous to being used, it should be kept covered up, and when wanted be re-beaten. If care be taken to secure it from the action of the atmosphere, it may thus remain covered up for a considerable period without its strength being in the least affected; and, indeed, some advantages are gained, for it sets sooner, is less liable to crack in the drying, and is harder when dry.

Grout, which is a cement containing a larger proportion of water than the common mortar, is used to run into the narrow interstices and irregular courses of rubble-stone walls; and as it is required to concrete in the course of a day, it is composed of mortar that has been a long time made and thoroughly beaten.

Mortar, composed of pure lime, sand, and water, may be employed in the linings of reservoirs and aqueducts, provided a sufficient time is allowed for it to dry before the water is let in; but if a sufficient time is not allowed, and the water is admitted while the mortar is wet, it will soon fall to pieces. There are, however, certain ingredients which may be put into the common mortar to make it set immediately under the water; or, if the quicklime composing the mortar contain in itself a certain portion of burnt clay, it will possess this property. For further information on this head the reader is referred to the sub-head—*Plastering*.

BRICKS.

The earth best adapted for the manufacture of brick is of a clayey loam, neither containing too much argillaceous matter, which causes it to shrink in the drying, nor too much sand, which has a tendency to render the ware both heavy and brittle. It should be dug two or three years before it is wrought, that it may, by an exposure to the action of the atmosphere, lose the extraneous matter of which it is possessed when first drawn from its bed; or, at least, should be allowed to remain one winter, that the frost may mellow and pulverize it sufficiently to facilitate the operation of tempering. As the quality of the brick is greatly dependent upon the tempering of the clay, great care should be taken to have this part of the process well done. Formerly the manner of performing it consisted in throwing the clay into

shallow pits, and subjecting it to the tread of men and oxen; but this method has of late been superseded by the clay or pug mill, which is a very eligible, though simple machine.

The clay or pug mill consists of a large vertical cone, having strong knives with a spiral arrangement and inclination fixed on its internal surface. Passing through the centre, and terminating in a pivot at the bottom, is a strong perpendicular shaft with similar radiating knives, so that the knives by the revolution of the shaft, cut, separate, and purify the clay, till it be reduced to a homogeneous paste, which passes through an orifice at the bottom into a receiver placed for that purpose. The clay is taken from the receiver to the moulder's bench, and is, either by a lad or a woman, cut into pieces somewhat larger than the mould, and passed on to the moulder, who works it into a mould, previously dipped in sand, and strikes off the superfluous parts with a flat smooth piece of wood. In this country the mould used is about ten inches in length, and five inches in breadth, and the bricks when burnt are about nine inches long, four and a half inches broad, and two and a half inches thick. The degree of shringing, however, is various, according to the temper and purity of the clay, and the degree of heat attained in the burning. A handy moulder is calculated to mould from about 5000 to 7000 per day. From the moulder's bench the bricks are carried to the hack, and arranged somewhat diagonally, one above the other, and two edgewise across, with a passage between the heads of each for the admission of air, till they be eight bricks in height. They are then left to dry. The time they take ere they rerequire shifting depends entirely upon the weather, which when fine will be but a few days: they are then turned and re-set wider apart, and in six or eight days are ready for the clamp or kiln.

Clamps are generally used in the vicinity of London. They are made of the bricks to be burnt, and are commonly of an oblong form. The foundation is made either with the driest of the bricks just made, or with the commonest kind of brick, called place bricks. The bricks to be burnt are arranged tier upon tier as high as the clamp is intended to be, and a stratum of breeze or cinders to the depth of two or three inches is strewed between each layer of bricks, and the whole is finally covered with a thick stratum of breeze. At the west end of the clamp a perpendicular fire-place of about three feet in height is constructed, and flues are formed

by arching the bricks over so as to leave a space of about a brick in width. The flues run straight through the clamp, and are filled with a mixture of coals, wood, and breeze, which are pressed closely together. If the bricks are required to be burnt off quickly, which can be accomplished in the space of from twenty to thirty days according to the state of the weather, the flues must not exceed six feet distance apart; but if there is no urgent demand, the flues need not be nearer than nine feet, and the clamp may be allowed to burn slowly.

Coke has been recommended as a more suitable fuel for bricks than either coal or wood, as the dimensions of the flues and the stratum of the fuel are not required to be so great, which, since the measurement of the clamp has been restricted to certain limits by the interference of the legislature, is a point of some consideration; besides, the heat arising from the coke is more uniform and more intense than what is produced by the other materials, so that the burning of the bricks is more likely to be perfect throughout. The saving which is thus produced may be calculated at about 32 per cent.

Kilns are also in common use, and are in many respects preferable to the clamp, as less waste arises, less fuel is consumed, and the bricks are sooner burnt. A kiln will burn about 20,000 bricks at a time. The walls of a kiln are about a brick and a half thick, and incline inwards towards the top, so that the area of the upper part is not more than 114 square feet. The bricks are set on flat arches, with holes left between them, resembling lattice-work; and, when the kiln is completed, are they covered with pieces of broken bricks and tiles, and some wood is kindled and put in to dry them gradually. When sufficiently dried, which is known by the smoke changing from a dark to a light transparent colour, the mouths of the kiln are stopped with pieces of brick, called *shinlog*, piled one upon another, and closed over with wet brick-earth. The shinlogs are carried so high as just to leave room for one faggot to be thrust into the kiln at a time, and when the brush-wood, furze, heath, faggots, &c. are put in, the fire is kindled, and the burning of the kiln commences. The fire is kept up till the arches assume a white appearance, and the flames appear through the top of the kiln; upon which the fire is allowed to slacken, and the kiln to cool by degrees. This process of alternately heating and slacking the kiln is continued till the bricks are thoroughly burnt, which, in

general, is in the space of forty-eight hours. The practice of steeping bricks in water after they have been burned, and then burning them again, has the effect of considerably improving the quality.

Bricks are of several kinds, the most usual of which are marls, stocks, and place bricks; but there is little difference in the mode of manufacturing them, except that great care is taken in preparing and tempering the marls.

The finest marls, called firsts, are selected for the arches of doorways, &c. and are rubbed to their proper form and dimensions: and the next best, called seconds, for the principal fronts. The colour, a light yellow, added to the smooth texture, and superior durability of the marls, give them the precedence of the other descriptions of brick.

Grey stocks are somewhat like the seconds, but of inferior quality.

Place bricks, sometimes called pickings, sandal, or samel bricks, are such as from being the outermost in the clamp or kiln, have not been thoroughly burned, and are, in consequence, soft, of uneven texture, and of a red colour.

There are also burrs or clinkers, arising from the bricks being too violently burned, and sometimes several bricks are found run together in the kiln. They derive their colour from the nature of the soil of which they are composed, which, in general, is very pure. The best kind are used as cutting bricks, and are called red rubbers. In old buildings they are very frequently to be seen ground to a fine smooth surface, and set in putty instead of mortar, as ornaments over arches, windows, door-ways, &c.; but though there are many beautiful specimens of red brick-work, yet these bricks cannot be judiciously used for the front walls of buildings. This objection arises from the colour being too heavy, and from its conveying to the mind, in the summer months, an unpleasant idea of heat; to which may be added, that as the fronts of the buildings have a greater or less proportion of stone and painted wood-work, the contrast in the colours is altogether injudicious. The colour of grey stocks, on the contrary, assimilates so much with the stones and paint, that they have obtained, in and near London, universal preference.

At the village of Hedgerley, near Windsor, red bricks are made which will stand the greatest heat: they are called Windsor bricks.

Bricks used for paving, are generally about an inch and a half in breadth; and, beside these, there are paving tiles,

which are made of a stronger clay, and are of a red colour. The largest are about twelve inches square, and one inch and a half thick: the next, though called ten-inch tiles, are about nine inches square, and one inch and a quarter thick.

About the year 1795, a patent was obtained by Mr. Cartwright, for an improved system of making bricks, of which the following extract will furnish the reader with all necessary information.

"Imagine a common brick, with a groove or rabate on each side down the middle, rather more than half the width of the side of the brick; a shoulder will thus be left on either side of the groove, each of which will be nearly equal to one quarter of the width of the side of the brick, or to one half of the groove or rebate. A course of these bricks being laid shoulder to shoulder, they will form an indented line of nearly equal divisions, the grooves or rebates being somewhat wider than the adjoining shoulders, to allow for the mortar or cement. When the course is laid on, the shoulders of the bricks, which compose it, will fall into grooves of the first course, and the shoulders of the first course, will fit into the grooves or rabates of the second, and so with every succeeding course. Buildings constructed with this kind of brick, will require no bond timbers, as an universal bond runs through the whole building, and holds all the parts together; the walls of which will neither crack nor bilge without breaking through themselves. When bricks of this construction are used for arches, the sides of the grooves should form the radii of the circle, of which the intended arch is a segment; yet if the circle be very large, the difference of the width at the top and bottom will be so very trifling, as to render a minute attention to this scarcely if at all necessary. In arch-work, the bricks may either be laid in mortar, or dry, and the interstices afterwards filled up by pouring in lime, putty, plaster of Paris, &c. Arches upon this principle, having any lateral pressure, can neither expand at the foot, nor spring at the crown, consequently they want no abutments, requiring only perpendicular walls to be let into, or to rest upon; neither will they want any superincumbent weight on the crown to prevent their springing up. The centres also may be struck immediately, so that the same centre, which never need be many feet wide, may be regularly shifted as the work proceeds. But the most striking advantage attending this invention is, the security it affords against the ravages of fire; for, from the peculiar properties of this kind of arch, requiring no abutments, it may be laid upon, or let into common walls, no stronger than what is required for timbers so as to admit of brick floorings."

Having said thus much on the laying of the foundation, the mixing of the mortar, and the manufacture of the brick, we shall next proceed to treat on the principles of the art of masonry, as practised in the present day.

MASONRY,

Is the art of cutting stones, and building them into a mass, so as to form the regular surfaces which are required in the construction of an edifice.

The chief business of the mason is to prepare the stones, make the mortar, raise the wall with the necessary breaks, projections, arches, apertures, &c., and to construct the vaults, &c. as indicated by the design.

A wall built of unhewn stone, whether it be built with mortar or otherwise, is called a *rubble wall.* Rubble work is of two kinds, coursed and uncoursed. In coursed rubble the stones are gauged and dressed by the hammer, and thrown into different heaps, each heap containing stones of equal thickness; and the masonry, which may be of different thicknesses, is laid in horizontal courses. In uncoursed rubble the stones are placed promiscuously in the wall, without any attention being paid to the placing them in courses; and the only preparation the stones undergo, is that of knocking off the sharp angles with the thick end of a tool called a *scabling* hammer. Walls are generally built with an ashlar facing of fine stone, averaging about four or five inches in thickness, and backed with rubb.e work or brick.

Walls backed with brick or uncoursed rubble, are liable to become convex on the outside, from the great number of joints, and the difficulty of placing the mortar, which shrinks in proportion to the quantity, in equal portions, in each joint; consequently, walls of this description are much inferior to those where the facing and backing are built of the same material, and with equal care, even though both of the sides be uncoursed. When the outside of a wall is faced with ashlar, and the inside is coursed rubble, the courses of the backing should be as high as possible, and set within beds of mortar. Coursed rubble and brick backings are favourable for the insertion of bond timber; but, in good masonry, wooden bonds should never be in continued lengths, as in case of either fire or rot the wood will perish, and the masonry will, by being reduced, be liable to bend at the place where the bond was inserted.

When timber is to be inserted into walls for the purposes of fastening buttons for plastering, or skirting, &c., the pieces of timber ought to be so disposed that the ends of the pieces be in a line with the wall.

In a wall faced with ashlar, the stones are generally about 2 feet or 2½ feet in length, 12 inches in height, and 8 inches in thickness. It is a very good plan to incline the back of each stone, to make all the backs thus inclined run in the same direction, which gives a small degree of lap in the setting of the next course; whereas, if the backs are paral-

lel to the front, there can be no lap where the stones run of an equal depth in the thickness of the wall. It is also advantageous to the stability of the wall to select the stones, so that a thicker and a thinner one may succeed each other alternately. In each course of ashlar facing, either with rubble masonry, or brick backing, thorough-stones should occasionally be introduced, and their number be in proportion to the length of the course. In every succeeding course, the thorough stones should be placed in the middle of every two thorough-stones in the course below; and this disposition of bonds should be punctually attended to in all cases where the courses are of any great length. Some masons, in order to prove that they have introduced sufficient bonds into their work, choose thorough-stones of a greater length than the thickness of the wall, and afterwards cut off the ends; but this is far from an eligible plan, as the wall is not only subject to be shaken, but the stone is itself apt to split. In every pier, between windows and other apertures, every alternate jamb-stone ought to go through the wall with its bed perfectly level. When the jamb-stones are of one entire height, as is frequently the case when architraves are wrought upon them, upon the lintel crowning them, and upon the stones at the ends of the courses of the pier which are adjacent to the architrave-jamb, every alternate stone ought to be a thorough-stone: and if the piers between the apertures be very narrow, no other bond-stone is required; but where the piers are wide, the number of bond-stones are proportioned to the space. Bond-stones must be particularly attended to in all long courses below and above windows.

All vertical joints, after receding about an inch with a close joint, should widen gradually to the back, thereby forming hollow spaces of a wedge-like figure, for the reception of mortar, rubble, &c. The adjoining stones should have their beds and vertical joints filled, from the face to about three quarters of an inch inwards, with oil and putty, and the rest of the beds must be filled with well-tempered mortar. Putty cement will stand longer than most stones, and will even remain permanent when the stone itself is mutilated. All walls cemented with oil-putty, at first look unsightly; but this disagreeable effect ceases in a year or less, when, if care has been taken to make the colour of the putty suitable to that of the stone, the joints will hardly be perceptible.

In selecting ashlar, the mason should take care that each stone invariably lays on its natural bed; as from careless-

ness in this particular, the stones frequently flush at the joints, and sooner admit the corrosive power of the atmosphere to take effect.

It ought also to be observed, that, in building walls, or insulated pillars of small horizontal dimensions, every stone should have its bed perfectly level, and be without any concavity in the middle; because, if the beds are concave, the joints will most probably flush when the pillars begin to sustain the weight of the building. Care should also be taken, that every course of masonry in such piers be of one stone.

Having thus given to the practical mason an outline of the subject of walling, we will proceed to the consideration of the more difficult branches of the art, that of constructing arches and vaults.

DEFINITIONS.

An *arch*, in masonry, is that part of a building which is suspended over a given plane, supported only at its extremities, and concave towards the plane.

The upper surface of an arch is called the *extrados;* and the under surface, or that which is opposite the plan, the *intrados.*

The supports of an arch are called the *spring walls.*

The *springing lines*, are those common to the supports and the intrados; or the line which forms the intersection of the arch with the surface of the wall which supports it.

The *chord*, or *span*, is a line extending from one springing line to the opposite one.

Section of the hollow of the arch, is a vertical plane, supposed to be contained by the span and the intrados.

The *height*, or *rise* of the arch, is a line drawn at right angles from the middle of the chord, or spanning line, to the intrados.

The *crown* of the arch is that part which the extremity of the perpendicular touches.

The *haunches*, or *flanks*, of the arch, are those parts of the curve between the crown and the springing line.

When the base of the section, or spanning line, is parallel to the horizon, the section will consist of two equal and similar parts, so that when one is applied to the other, they will be found to coincide.

Arches are variously named according to the figure of the section of a solid that would fill the void, as ***circular, ellip-***

tical, cycloidal, catenarian, parabolical, &c. There are also *pointed, composite,* and *lancet,* or *Gothic arches.*

A *rampant arch* is when the springing lines are of two unequal heights.

When the intrados and extrados of an arch are parallel, it is said to be *extradossed.*

There are, however, other terms much used by masons; for example, the semicircular are called *perfect arches,* and those less than a semicircle, *imperfect, surbused,* or *diminished* arches.

Arches are also called *surmounted,* when they are higher than a semicircle.

A *vault* is an arch used in the interior of a building, overtopping an area of a given boundary, as a passage, or an apartment, and supported by one or more walls, or pillars, placed without the boundary of that area.

Hence an arch in a wall is seldom or never called a vault; and every vault may be called an arch, but every arch cannot be termed a vault.

A *groin vault,* is a complex vault, formed by the intersection of two solids, whose surfaces coincide with the intrados of the arches, and are not confined to the same heights. An arch is said to stand upon splayed jambs, when the springing lines are not at right angles to the face of the wall.

In the art of constructing arches and vaults, it is necessary to build them in a mould, until the whole is closed: the mould used for this purpose is called a *centre.* The intrados of a simple vault is generally formed of a portion of a cylinder, cylindroid, sphere, or spheroid, that is, never greater than the half of the solid: and the springing lines which terminate the walls, or when the vault begins to rise, are generally straight lines, parallel to the axis of the cylinder, or cylindroid.

A circular wall is generally terminated with a spherical vault, which is either hemispherical, or a portion of a sphere less than an hemisphere.

Every vault which has an horizontal straight axis, is called a *straight vault;* and in addition to what we have already said, the concavities which two solids form at an angle, receive likewise the name of arch.

An arch, when a cylinder pierces another of a greater diameter, is called *cylindro-cylindric.* The term cylindro is applied to the cylinder of the greatest diameter, and the term cylindric to the less.

Plate 78. _From 551 to 554._ Page 641.

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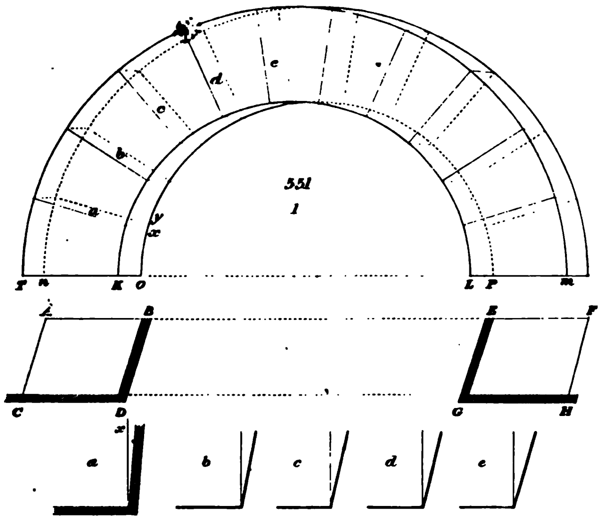

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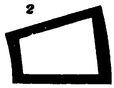

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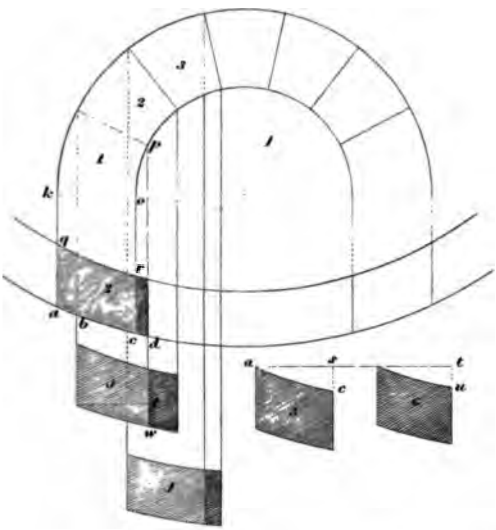

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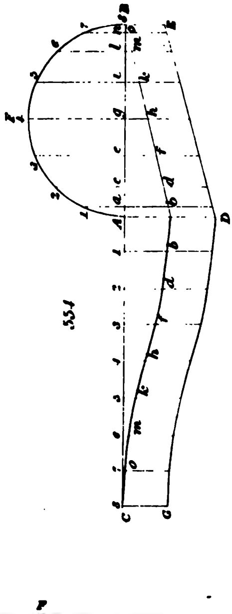

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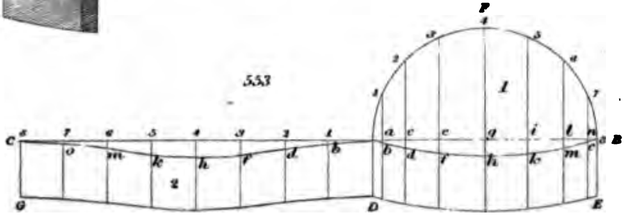

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If a cylinder intersect a sphere of greater diameter than the cylinder, the arch is called a *sphero-cylindric arch;* but on the other hand, if a sphere pierce a cylinder of greater diameter than the sphere, the arch is called a *cylindro-spheric* arch,

If a cylinder pierce a cone, so as to make a complete perforation through the cone, two complete arches will be formed, called *cono-cylindric arches;* but, on the contrary, if a cone pierce a cylinder, so that the concavity made by the cone is a conic surface, the arch is called *cylindro-conic* arch.

If, in a straight wall, there be a cylindric aperture continuing quite through it, two arches will be formed, called *plano-cylindric arches.*

Every description of arch is, in a similar manner to the above, denoted by the two preceding words; the former ending in *o*, signifying the principal vault, or surface cut through; and the latter in *ic*, signifying the description of the aperture which pierces or intersects the wall or vault.

When groins are introduced merely for use, they may be built either of brick or stone; but, when introduced by way of proportion or decoration, their beauty will depend on the generating figures of the sides, the regularity of the surface, and the acuteness of the angles, which should not be obtunded. In the best buildings, when durability and legance are equally required, they may be constructed of wrought stone; and, when elegance is wanted, at a trifling expense, of plaster, supported by timber ribs.

In stone-cutting, a narrow surface formed by a point or chisel, on the surface of a stone, so as to coincide with a traight edge, is called a *draught.*

The formation of stone arches has always been considered a most useful and important acquisition to the operative mason; in order, therefore, to remove any difficulties which might arise in the construction of arches of different descriptions, both in straight and circular walls, we shall here introduce a few examples, which, it is hoped, with careful examination, will greatly facilitate a knowledge of some of the most abstruse parts of the art.

Fig. 551, No. 1. To find the moulds necessary for the construction of a semicircular arch, cutting a straight wall obliquely.

Let ABCDEFGH be the plan of the arch; IKLM the outer line; and NOPQ the inner line on the elevation.

a b c d e, on the elevation, shows the bevel of each joint or bed from the face of the wall; and *a b c d e* below, gives the mould for the same, where *x y* on the elevation corresponds with *x y* at *a*.

The arch mould, fig. 551, No. 2, is applied on the face of the stone, and on being applied to the parts of the plan, gives, of course, the beve of each concave side of the stone with the face, that is K to O, on the elevation.

Fig. 552. To find the mould for constructing a semicircular arch in a circular wall.

No. 1 is the elevation of the arch; and No. 2 the plan of the bottom bed from *q* to *r*.

a to *b* is what the arch gains on the circle from the bottom bed *k o* to *l*; and *c* to *d* is the projection of the intrados to *p*, on the joint *l. p*.

Nos. 2, 3, 4, are plans of the three arch-stones, 1, 2, 3, in the elevation; and Nos. 5 and 6 are moulds to be applied to the beds of stones 1 and 2, in which *s c* equals *s c* in No. 2, and *t w* equals *t w* in No. 3.

In No. 1, *k l p o* is the arch or face mould.

When the reader is thoroughly proficient in the construction of arches, under given datas, as the circumstances of the case may point out, he may proceed to investigate the principles of spherical domes and groins.

Figs. 553 and 554 show the principles of developing the soffits of the arches in the two preceding examples. In each the letters of reference are alike, and the operation is precisely the same.

Let ABDE be the plan of the opening in the wall; and AFB the elevation of the arch: produce the chord AB to C, divide the semicircle AFB into any number of parts, the more the better, and with the compasses set to any one of these divisions, run it as many times along AC as the semicircle is divided into; then draw lines, perpendicular to BC, through every division in the semicircle and the line CA, and set the distance 1 *b*, 2 *d*, 3 *f*, &c. respectively equal to *a b*, *c d*, *e f*, &c. and then by tracing a curve through these points, and finding the points in the line GD, in the same manner, the soffit of the arch is complete.

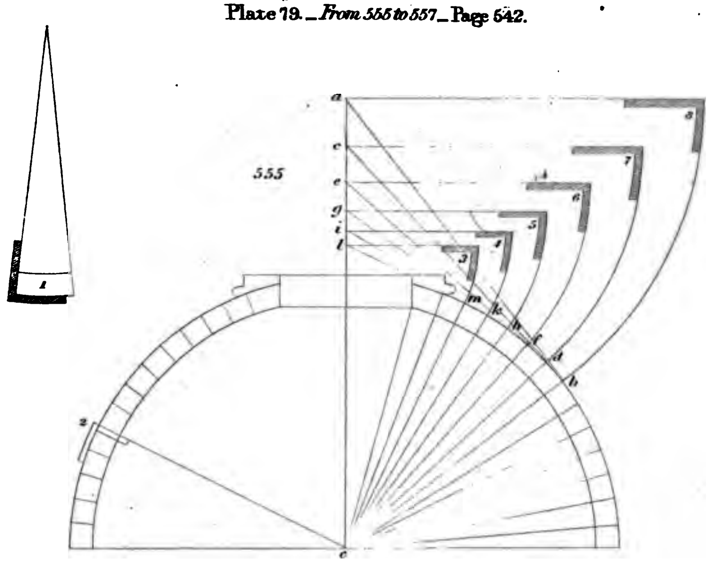
Fig. 555, shows the method of constructing spherical domes.

No. 1 mould is applied on the spherical surface to the vertical joints; and No. 2 mould on the same surface to the other joints; and in both cases, the mould tends to the centre of the dome.

3, 4, 5, 6, 7, and 8, are moulds which apply on the convex surface to the horizontal joint, the lines *a b*, *c d*, *e f*, &c. being at right angles to the different radii, *b c*, *d c*, *f c*, &c. and produced until they intersect the perpendicular *a c*; the different intersections are the centres which give the circular leg of the mould, and the straight part gives the horizontal joint.

Fig. 556 exhibits the plan of a groined vault.

Lay down the arch, either at the full or half size, on a floor or piece of floor-cloth, then divide and draw on the plan the number of joints in the semicircular arch, and from the intersections with the diagonals, draw the transverse joints on the plan, and produce them till they touch the intradoes of the elliptical arch, the curve of which may be found by setting the corresponding distances from the line of the base to the curve; thus *a b* equal to *a b*. This being accomplished, draw the joints of the ellipti-



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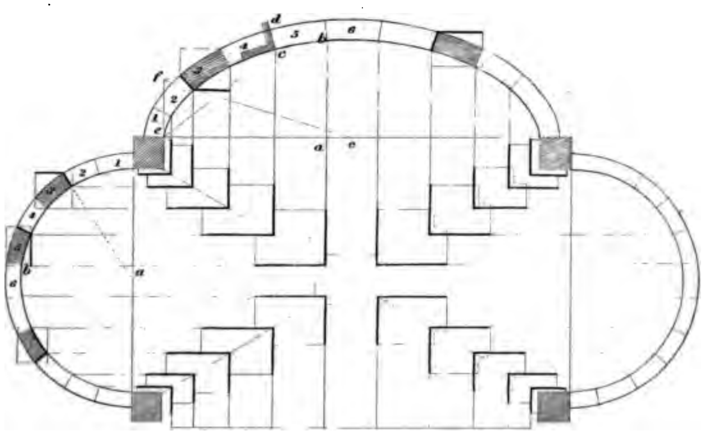
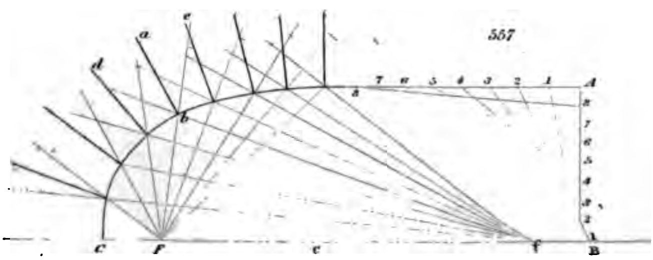




557

Jas J Neale

cal arch in the manner of which we give *c d*, as a specimen. To draw the joint *c d*, draw the chord *e c* and bisect it, draw a line from the centre *c*, through the bisecting point, and produce it till it touches the perpendicular *e f*; and *c d*, being at right angles to *e f*, will be the joint required. In the same manner the others are found.

By examination, it will be seen, that a rectangle circumscribing the mould 3, 3, gives the size of the stone in its square state, and, that if each stone in both arches be thus enclosed, the dimensions for each will be found, as also the position in which the moulds must be placed. The dark lines give the different bevels which must be carefully prepared and applied to the stones in the manner represented in the figure.

Fig. 557. To draw the joints of the stones for an elliptical arch in a wall, &c.

The curve is here described by the intersection of lines, which, certainly, gives the most easy and pleasing curve, as segments of circles apply only under certain data, or in the proportion which the axis major has to the axis minor, while the intersection of lines apply to any description of ellipsis. Find the foci F. In an ellipsis the distance of either focus from one extremity of the axis minor is equal to the semi-axis major; that is, DF is equal to *c* C. Then to find any joint, *a b*, draw lines from both foci through the point *b*, as F *e*, *f d*, and bisect the angle *d b e* by the line *a b*, which is the joint required.

Having thus given a general outline of the principles of masonry, and accompanied the same with a few examples on the most abstruse parts of the art, we shall conclude this part of our treatise with the methods employed in the mensuration of masons' work.

Rough stone or marble is measured by the foot cube: but in measuring for workmanship, the superficies or surface, for plain work, is measured before it is sunk. In measuring ashlar, one bed and one upright joint are taken and considered plain work. In taking the plain sunk, or circular work, and the straight moulded, or circular moulded work, particular care is required to distinguish the different kinds of work in the progress of preparing the stone. In measuring strings, the weathering is denominated *sunk work*, and the grooving *throatings*.

Stone cills to windows, &c. are, in general, about $4\frac{1}{4}$ inches thick and 8 inches broad, and are weathered at the top, which reduces the front edge to about 4 inches, and the horizontal surface at the top to about $1\frac{1}{2}$ inch on the inside; so that the part taken away is $6\frac{1}{2}$ inches broad and three quarters of an inch deep. Cills, when placed in the wall, generally project about $2\frac{1}{2}$ inches. The horizontal part left on the inside of the cill is denominated *plain work;* and the sloping part *sunk work;* and in the dimension book are entered thus,—

$1\frac{1}{4}$
4
$2\frac{3}{4}$

8 inches the breadth of the plain work in the cill according to the above dimensions,—then

	4 8	2 8	Plain work.
	4 $6\frac{1}{2}$	2 2	Sunk work.
2	8 4	6	Plain to ends.
	4 0		of throating.

No account is taken of the sawing.

Cornices are measured by girthing round the moulded parts, that is, the whole of the vertical and under parts, called moulded work:—for example, suppose a cornice project one foot, girth two feet, and is 40 feet in length, then the dimensions will be entered as under,—

40 2	80	Moulded work.
40 1	40	Sunk work at top.

All the vertical joints must be added to the above.

Cylindrical work is measured in the girth; and the surface is calculated to be equivalent to plain work twice taken.

For example, suppose it be required to measure the plain work or a cylinder, 10 feet long, and 5 feet in circumference, the dimensions would then be entered

10 0 5 0	500 Sup'. plain work, double measure.	

Paving-slabs and chimney-pieces are found by superficial measure, as also are stones under two inches thick.

The manner in which the dimensions of a house are taken, vary according to the place and the nature of the agreement.

In Scotland, and most parts of England, if the builder engages only for workmanship, the dimensions are taken round the outside of the house for the length, and the height is taken for the width, and the two multiplied

together gives the superficial contents. This, however, applies only when the wall is of the same thickness all the way up; and when not, as many separate heights are taken as there are thicknesses. This mode of measuring gives something more than the truth, by the addition of the four quoins, which are pillars of two feet square; but this is not more than considered sufficient to compensate the workmen for the extra labour in plumbing the quoins.

If there be a plinth, string, course-cornice, or blocking course, the height is taken from the bottom of the plinth to the top of the blocking course, including the thickness of the same; that is, the measurer takes a line or tape and begins, we will suppose, at the plinth, then stretching the line to the top, bends it into the offset, or weathering, and, keeping the corner tight at the internal angle, stretches the line vertically upon the face of the wall, from the internal angle to the internal angle of the string; then girths round the string to the internal angle at the top of the string, and keeping the line tight at the upper internal angle, stretches it to meet the cornice; he then bends it round all the mouldings to the internal angle of the blocking course, from which he stretches the string up to the blocking course, to the farther extremity of the breadth of the top of the same; so that the extent of the line is the same as the vertical section stretched out: this dimension is accounted the height of the building.

With respect to the length, when there are any pilasters, breaks, or recesses, the girth of the whole is taken at the length. This method is, perhaps, the most absurd of any admitted in the art of measuring; since this addition in height and length, is not sufficient to compensate for the value of the workmanship on the ornamental parts.

The value of a rood of workmanship must be first obtained by estimation, that is, by finding the cost of each kind of work, such as plinth, strings, cornices, and architraves, &c. and adding to them the plain ashlar work, and the value of the materials, the amount of which, divided by the number of roods contained in the whole, give the mean price of a single rood. When the apertures or openings in a building are small, it is not customary to make deductions either for the materials or workmanship which are there deficient, as the trouble of plumbing and returning the quoins, is considered equivalent to the deficiency of materials occasioned by such aperture.

Elsam's Gentleman's and Builder's Assistant, gives the following information on the practice of measuring rough stone work.

To find the number of perches contained in a piece of rough stone-work.

If the wall be at the standard thickness, that is, 12 inches high, 18 inches thick, and 21 feet long, divide the area by 21, and the quotient, if any, will be the answer in perches, and the remainder, if any, is feet. If the wall be more or less than 18 inches thick, multiply the area of the wall by the number of inches in thickness, which product, divided by 18, and that quotient by 21, will give the perches contained.

Example. A piece of stone-work is 40 feet long, 20 feet high, and 24 inches thick, how many perches are contained in it?

```
          40 length.
          20 height.
        ----
         800
          24
        ----
        3200
       1600
      ------ 21)       P.  F.  In.
  18) 19200  (1066   ( 50  16  8
      18      105
      ---     ---
       120     16
       108    ---
       ---
        120
        108
        ---
          12 equal to 8 inches.
```

The method last described, of finding the value of mason's work, is usually adopted, the perch being the standard of the country; but the most expeditious way of ascertaining the value, is to cube the contents of the wall, and to charge the work at per foot. To ascertain the value of common stone-work, a calculation should be made of the prime cost of all the component parts, consisting of the stones in the quarry, the expense of quarrying, land-carriage to the place where it is to be used, with the extra trouble and consequent expense in carrying the stone one, two, three, or more stories higher. Also the price of the lime when delivered, together with the extra expense of wages to workmen, if in the country; all these circumstances must be taken into consideration in finding the value of a perch of common stone-work, the expense of which will be found to vary according to

local circumstances, in degrees scarcely credible; wherefore a definite price cannot, with propriety, be fixed.

BRICKLAYING

In building upon an inclined plane, or rising ground, the foundation must be made to rise in a series of level steps, according to the general line of the ground, to insure a firm bed for the courses, and prevent them from sliding; for if this mode be not adopted, the moisture in the foundations in wet weather, will induce the inclined parts to descend, to the manifest danger of fracturing the walls and destroying the building.

In walling, in dry weather, when the work is required to be firm, the best mortar must be used; and the bricks must be wetted, or dipped in water, as they are laid, to cause them to adhere to the mortar, which they would not do if laid dry; for the dry sandy nature of the brick absorbs the moisture of the mortar and prevents adhesion.

In carrying up the wall, not more than four or five feet of any part should be built at a time; for, as all walls shrink immediately after building, the part which is first carried up will settle before the adjacent part is carried up to it, and, consequently, the shrinking of the latter will cause the two parts to separate; therefore, no part of a wall should be carried higher than one scaffold, without having its contingent parts added to it. In carrying up any particular part, the ends should be regularly sloped off, to receive the bond of the adjoining parts on the right and left.

There are two descriptions of bonds; *English bond*, and *Flemish bond*. In the *English bond*, a row of bricks is laid lengthwise on the length of the wall, and is crossed by another row, which has its length in the breadth of the wall, and so on alternately. Those courses in which the lengths of the bricks are disposed through the length of the wall, are termed *stretching courses*, and the bricks *stretchers*: and those courses in which the bricks run in the thickness of the lengths of the walls, *heading courses*, and the bricks *headers*.

The other description of bond, called *Flemish bond*, consists in placing a header and a stretcher alternately in the same course. The latter is deemed the neatest, and most elegant; but, in the execution is attended with great inconvenience, and, in most cases, does not unite the parts of a

wall with tne same degree of firmness as the English bond. In general, it may be observed, that, whatever advantages are gained by the English bond in tying a wall together in its thickness, they are lost in the longitudinal bond; and *vice-versa*. To remove this inconvenience, in thick walls, some builders place the bricks in the cone at an angle of forty-five degrees, parallel to each other, throughout the length of every course, but reversed in the alternate courses; so that the bricks cross each other at right angles. But even here, though the bricks in the cone have sufficient bond, the sides are very imperfectly tied, on account of the triangular interstices formed by the oblique direction of the internal bricks against the flat edges of those in the outside.

Concerning the English bond, it may be observed, that, as the longitudinal extent of a brick is nine inches, and its breadth four and a half, to prevent two vertical joints from running over each other at the end of the first stretcher from the corner, it is usual, after placing the return corner stretcher, which occupies half of the length of this stretcher, and becomes a header in the face, as the stretcher is below, to place a quarter brick on the side, so that the two together extend six inches and three-quarters, being a lap of two inches and a half for the next header. The bat thus introduced is called a *closer*. A similar effect may be obtained by introducing a three-quarter bat at the corner of the stretching course, so that the corner header being laid over it, a lap of two inches and a quarter will be left, at the end of the stretchers below, for the next header, which being laid on the joint below the stretchers, will coincide with its middle.

In the winter, it is very essential to keep the unfinished wall from the alternate effects of rain and frost; for if it is exposed, the rain will penetrate into the bricks and mortar, and, by being converted into ice, expand, and burst or crumble the materials in which it is contained.

The decay of buildings, so commonly attributed to the effects of time, is, in fact, attributable to this source; but as finished edifices have only a vertical surface, the action and counter-action of the rain and frost extend not so rapidly as in an unfinished wall, where the horizontal surface permits the rain and frost to have easy access into the body of the work. Great care, therefore, must be taken as soon as the frost or stormy weather sets in, to cover the un-

finished walls, either with straw, which is the most common, or weather boarding.

When weather boarding is employed, it is advisable to have a good layer of straw between the work and the boarding, and to place the boarding in the form of stone-coping, to throw the water off equally on both sides.

A number of very pleasing cornices and other ornaments may be formed in brick-work, by the mere disposition of the bricks, without cutting; and if cut, a simple champher will be sufficient. A great defect, however, is very often observable in these ornaments, particularly in the bulging of arches over windows; which arises from mere carelessness, in rubbing the bricks too much on the inside; whereas, if due care were taken to rub them exact to the gauge, their geometrical bearings being united, they would all tend to one centre, and produce a well-proportioned and pleasing effect.

In steining wells, it is necessary first to make a centre, consisting of a boarding of inch or inch and a half stuff, ledged within with three circular rings, upon which the bricks, all headers, are laid. The vacuity between the bricks towards the boarding, are to be filled in with tile or other pieces of brick. As the well-sinker proceeds to excavate the ground, the centre with its load of bricks sinks, and another similarly charged is laid upon it, and another upon that, and so on till the wall is complete, the centreing remaining with the brick-work. This plan is generally adopted in London, at least where the soil is sandy and loose; where it is firm, centreings are not requisite. In the country, among many other methods, the following is most approved:—rings of timber, without the exterior boarding, are used; upon the first ring, four or five feet of bricks are laid, then a second ring, and so on. But the mode before described is by far the most preferable; as in the latter the sides of the brick-work are apt to bulge in sinking, particularly if great care be not taken in filling and ramming the sides uniformly, so as to keep the pressure regular and equal. In steining wells and building cesspools, a rod of brick-work will require at least 4760 bricks.

As the construction of walls, arches, groins, &c. in brick-work, approximates so nearly to that of stone-work, and as the same observations generally apply, further information would, perhaps, be considered superfluous; we shall, therefore, conclude this article with some practical observations on the measuring of brick-work.

Brick-work is measured and valued by the rod. The contents of a rod of brick-work is 16½ feet square; consequently, the superficial rod contains 272·25, or 272¼ square feet; but as the quarter has been found troublesome in calculation, 272 superficial feet has been admitted as the standard.

The standard thickness of a brick wall is 1½ brick laid lengthwise; therefore, if 272 square feet be multiplied by 13 inches, the result will be 306 cubic feet, or a rod.

A rod of standard brick-work, making the necessary allowance for mortar and waste, will require 4500 bricks; but this quantity is of course ruled by the size of the brick, and the closeness of the joints.

A foot of reduced brick-work requires 17 bricks; a foot superficial of marl facing, laid in Flemish bond, 8 bricks; and a foot superficial of gauged arches, 10 bricks. In paving, a yard will require 82 paving bricks, or 48 stock bricks, or 38 bricks laid flat.

A square of tiling contains 100 superficial feet; and requires of plain tiles, 800 at a six-inch gauge, 700 at a seven-inch gauge, or 600 at an eight-inch gauge.

The distances between the respective laths must depend on the pitch of the roof; and one roof may require a 6, 7, and 8 inch gauge. For instance, a kirt roof will require, in the kirt part, a 7½ or 8 inch gauge, and in the upper part 6, 6½, or 7 inch, the gauge decreasing in the ratio of the angle of elevation.

A square of plain tiling will require a bundle of laths, more or less, according to the pitch; with two bushels of lime, one bushel of sand, and a peck of tile-pins.

Laths are sold by the thousand, or bundle; and each bundle is supposed to contain 100 laths, though the exact number depends on the length; the 3 feet containing 5 score, the 4 feet 4 score, the 5 feet 3 score, and so on in proportion.

A square of pan-tiling requires 180 tiles, laid at a ten-inch gauge; and one bundle, containing 12 laths, ten feet long.

In lime measure, 25 struck bushels, or 100 pecks, make a hundred of lime; 8 gallons, a bushel dry measure; and 268 cubic inches, one gallon.

In measuring sand, 24 heaped, or 30 struck bushels make one load; and 24 cubic feet weighs one ton.

A load of mortar, which ought to contain half a hundred ot lime, with a proportionate quantity of sand, is 27 cubic feet.

Excavations of the earth are measured by the number of cubic yards which they contain, therefore, to find the number of cubic yards in a trench, find the solidity of the trench in cubic feet, and divide it by 27, the number of cubic feet in a yard, and the quotient, is the number of cubic yards, and the remainder the number of cubic feet.

For example, the length of a trench is 60 feet, the depth 3 feet, and the breadth 2 feet.

```
        60
         3
       ---
       180
         2
       --- yds. ft.
  27 ) 360 ( 13   9 the answer
        27
       ---
        90
        81
       ---
         9
       ---
```

In the horizontal dimensions, if the trench be wider at the top than it is at the bottom, and equal at the ends, take half the sum of the two dimensions for a mean breadth; and if the breadth of one end of the trench exceed that of the other, so as to have two mean breadths, differing from each other, take half the sum of the two added together, as a mean breadth of the whole.

In measuring the footing of a wall, multiply the length and the height of the courses together; then multiply the product by the number of half bricks in the mean breadth, divide the last product by 3, and the quotient is the answer in reduced feet. Instead of measuring the height of the footing, it is customary to allow three inches to each course in height, or multiply the number of courses by 3, which gives the height in inches.

To find the contents in rods of a piece of brick work.

Case I. If the wall be of the standard thickness, divide the area of the wall by 272, and the quotient is the number of rods, and the remainder the number of feet; but if the wall be either more or less than a brick and a half in thickness, multiply the area of the wall by the number of half bricks, that is, the number of half lengths of a brick; divide the product by 3, which will reduce the wall to the standard thickness of $1\frac{1}{2}$ brick, then divide the quotient by 272, and it will give the number of rods,

Case II. Divide the number of cubic feet contained in the wall by 306; the quotient will give the number of rods, and the remainder the number of cubic feet.

Case III. Multiply the number of cubic feet in a wall by 8; divide the

product by 9; and the quotient will give the area of the wall at the standard: divide this standard area by 272, and the quotient will give the number of rods; the remainder the reduced feet.

Example. The length of a wall is 60 feet, the height 20 feet, and the thickness equal to the length of three bricks; it is therefore required to know how many rods of brick-work is contained in the said wall?

```
By Case I.        60
                  20
                ----
                1200
                   6
                ----
            3 ) 7200
                ----
          272 ) 2400 ( 8 rods 224 feet the answer.
                2176
                ----
                 224
                ====

Case II           60
                  20
                ----
                1200
                 2.3  thickness of wall
                ----
                2400
                 300
                ----
          306 ) 2700 ( 8 rods 252 feet the answer.
                2448
                ----
                 252
                ====

Case III.         60
                  20
                ----
                1200
                 2.3
                ----
                2400
                 300
                ----
                2700
                   8
                ----
           9 ) 21600
                ----
          272 ) 2400 ( 8 rods 224 feet, as in Case I
                2176
                ----
                 224
                ====
```

In the calculation of brick-work, where there are several walls of different thicknesses, it will be quite unnecessary to use the divisors 3 and 272, as will be hereafter shown.

In taking dimensions for workmanship, it is usual to allow the length of each wall on the external side, to compensate for plumbing the angles; but this practice must not be resorted to for labour and materials, as it gives too much quantity in the height of the building or story by two pillars of brick; and in the horizontal dimensions by the thickness of the walls.

In measuring walls, faced with bricks of a superior quality, most surveyors measure the whole as common work, and allow an additional price per rod for the facing, as the superior excellence of the work, and quality of the bricks may deserve.

Every recess or aperture made in any of the faces must be deducted; but an allowance per foot lineal should be made upon every right angle, whether external or internal, excepting when two external angles may be formed by a brick in breadth, and then only one of them must be allowed.

Gauged arches are sometimes deducted and charged separate; but as the extra price must be allowed in the former case, it will amount to the same thing.

In measuring walls containing chimneys, it is not customary to deduct the flues; but this practice, so far as regards the materials, is unjust, though, perhaps, by taking the labour and materials together, the overcharge, with respect to the quantity of bricks and mortar, may, in some degree, compensate for the loss of time: on the other hand, if the proprietor finds the materials, it is not customary to allow for the trouble of forming the flues, which, consequently, is a loss to the contractor who has engaged by task-work or measure.

If the breast of a chimney project from the face of the wall, and is parallel to it, the best method is, to take the horizontal and vertical dimensions of the face, multiply them together, and multiply the product by the thickness, taken in the thinnest part, without noticing the breast of the chimney; then find the solidity of the breast itself, add these solidities together, and the sum will give the solidity of the wall, including the vacuities, which must be deducted for the real solidity. Nothing more is necessary to be said of the shaft, than to take its dimensions in height, breadth, and thickness, in order to ascertain its solidity.

If a chimney be placed at an angle, with the face of tne breast intersecting the two sides of the wall, the breast of the chimney must be considered a triangular prism. To take the dimensions :—from the intersections of the front of the breast into the two adjacent walls, draw two lines on the floor, parallel to each adjacent wall; then the triangle on the floor, included between the front and these lines, will be equal to the triangle on which the chimney stands, and, consequently, equal to the area of the base. To attain the area of the triangular base, the dimensions may be taken in three various ways, almost equally easy; one of which is, to take the extent of the base, which is the horizontal dimension of the breast, and multiply it by half of the perpendicular; or multiply the whole perpendicular by half the base: but, as this calculation would, in cases of odd numbers, run somewhat long, a more preferable method is, to multiply the whole base by the whole perpendicular, and take half of the product, which will give the area on which the chimney stands; and which, multiplied by the height, gives the solid contents of the chimney. From this contents is to be deducted the vacuity for the fire-place.

A row of plain tiles, laid edge to edge, with their broad surfaces parallel to the termination of a wall, so as to project over the wall at right angles to the vertical surface, is called *single plain tile creasing*; and two rows, laid one above the other, the one row breaking the joints of the other, are called *double plain tile creasing*.

Over the plain tile creasing a row of bricks is placed on edge, with their length in the thickness of the wall, and are called a *barge course*, or *cope*.

The bricks in gables, which terminate with plain tile creasing coped with bricks, in order to form the sloping bed for the plain tile creasing, must be cut, and the sloping of the bricks thus, is called *cut splay*.

Plain tile creasing and cut splay are charged by the foot run; and the latter is sometimes charged by the superficial foot.

A brick wall built in pannels between timber quarters is called *brick nogging*; and is generally measured by the yard square, the quarters and nogging pieces being included in the measure.

Pointing is the filling up the joints of the bricks after the walls are built. It consists in raking out some of the mortar from the joints, and filling them again with blue mortar, and in one kind of pointing, the courses are simply

marked with the end of a trowel, called *flat-joint pointing;* but if, in addition to flat-joint pointing, plaster be inserted in the joint with a regular projection, and neatly paved to a parallel breadth, it is termed *hick pointing*, or *hick-joint pointing*, or formerly, *hick, and patt.* Pointing is measured by the foot superficial, including in the price, mortar, labour, and scaffolding.

Rubbed and gauged work is set in putty or mortar; and is measured either by the foot superficial, or the foot run, according to the manner in which it is constructed.

In measuring canted bow windows, the sides are considered as continued straight lines; but the angles on the exterior side of the building, whether they be external or internal, are allowed for in addition, and paid for under the denomination of *run of bird's mouth.* All angles within the building, if oblique, from whatever cause they are made, either by straight or circular bows, or the splays of windows, are allowed for, under the head o. *run of cut splay.*

Brick cornices are measured by the lencal foot; but as various kinds of cornices require more or less difficulty in the execution, the price must depend on the labour and the value of the material used.

Garden walls are measured the same as other walls, but if 'nterrupted by piers, the thin part may be measured as in common walling, and the piers by themselves, making an allowance, at per foot run, for the right angles The coping is measured by itself, according to the kind employed.

Paving is laid either with bricks, or tiles, and is measured by the yard square. The price, per yard, is regulated by the manner in which the bricks or tiles are laid, whether flat or edge-ways, or whether any of them be laid in sand or mortar.

The circular parts of drains may be reduced either to the standard, or the cubic foot; and the number of rods may, if required, be taken. The mean dimensions of the arch may be found, by taking the half sum of the exterior and interior circumferences; but, perhaps, it were better to make the price of the common measure, whether it be a foot, yard, or rod, greater as the diameter is less; but as the reciprocal ratio would increase the price too much in small diameters, perhaps prices at certain diameters would be a sufficient regulation.

The following tables will be found an acquisition to those persons to whom a saving of time is an object:—

TABLE I.

This Table shews what quantity of bricks are necessary to construct a piece of brick-work of any given dimensions, from half a brick to two bricks and a half in thickness; and by which the number for any thickness may be found.

This Table is at the rate of 4500 bricks to the rod of reduced brick-work, including waste.

Area of the face of wall.	The number of bricks thick and the quantity required.				
	½ brick.	1 brick.	1½ brick.	2 bricks.	2½ bricks.
1	5	11	16	22	27
2	11	22	33	44	55
3	16	33	49	66	82
4	22	44	66	88	110
5	27	55	82	110	137
6	33	66	99	132	165
7	38	77	115	154	193
8	44	88	132	176	220
9	49	99	148	198	288
10	55	110	165	220	275
20	110	220	330	441	551
30	165	330	496	661	827
40	220	441	661	882	1102
50	275	551	827	1102	1378
60	330	661	992	1323	1655
70	386	772	1158	1544	1930
80	441	882	1323	1764	2205
90	496	992	1488	1985	2480
100	551	1102	1654	2205	2757
200	1102	2205	3308	4411	5514
300	1654	3308	4963	6617	8272
400	2205	4411	6617	8823	11,029
500	2757	5514	8272	11,029	13,786
600	3308	6617	9926	13,235	16,544
700	3860	7720	11,580	15,441	19,301
800	4411	8823	13,235	17,647	22,058
900	4963	9926	14,889	19,852	24,816
1000	5514	11,029	16,544	22,058	27,573
2000	11,029	22,058	33,088	44,117	55,147
3000	16,544	33,088	49,632	66,176	82,720
4000	22,058	44,117	66,176	88,235	110,294
5000	27,573	55,147	82,720	110,294	137,867
6000	33,088	66,176	99,264	132,352	165,441
7000	38,602	77,205	115,808	154,411	193,014
8000	44,117	88,235	132,352	176,470	220,588
9000	49,632	99,264	148,896	198,529	248,161
10,000	55,147	110,294	165,441	220,588	275,735
20,000	110,294	220,588	330,882	441,176	551,470
30,000	165,441	330,882	496,323	661,764	827,205
40,000	220,588	441,176	661,764	882,352	1,102,940
50,000	275,735	551,470	827,205	1,102,940	1,378,675
60,000	330,882	661,764	992,646	1,323,528	1,654,410
70,000	386,029	772,058	1,158,087	1,544,116	1,930,145
80,000	441,176	882,352	1,323,528	1,764,704	2,205,880
90,000	496,323	992,646	1,488,969	1,985,292	2,481,615

The left-hand column contains the number of superficial feet contained in the wall to be built: the adjacent columns shew the number of bricks required to build a wall of the different thicknesses of ½, 1, 1½, 2, and 2½ bricks.

Example. Suppose it be required to find the number of bricks necessary to build a wall 1 brick thick, containing an area of 5760 feet? First look for 5000 in the left hand column, and you will find that it takes 55,147 bricks, add to this quantity, the number necessary for each of the other component parts, and we shall have the following

5000	will require	55147
700	. . . .	7720
60	. . . .	661
5760		63,528

TABLE II.

Shews the number of rods contained in any number of superficial feet, from 1 to 10,000, and from ½ a brick to 2½ bricks; and thence by addition, to any number, and to any thickness, at the rate of 4500 bricks to the rod.

Feet sup.	½ brick.				1 brick.				1½ brick.				2 bricks.				2½ bricks.			
	R.	Q.	F.	In.	R.	Q.	F.	In.	R.	Q.	F.	In.	R.	Q.	F.	In.	R.	Q.	F.	In.
1	0	0	0	4	0	0	0	8	0	0	1	0	0	0	1	4	0	0	1	8
2	0	0	0	8	0	0	1	4	0	0	2	0	0	0	2	8	0	0	3	4
3	0	0	1	0	0	0	2	0	0	0	3	0	0	0	4	0	0	0	5	0
4	0	0	1	4	0	0	2	8	0	0	4	0	0	0	5	4	0	0	6	8
5	0	0	1	8	0	0	3	4	0	0	5	0	0	0	6	8	0	0	8	4
6	0	0	2	0	0	0	4	0	0	0	6	0	0	0	8	0	0	0	10	0
7	0	0	2	4	0	0	4	8	0	0	7	0	0	0	9	4	0	0	11	8
8	0	0	2	8	0	0	5	4	0	0	8	0	0	0	10	8	0	0	13	4
9	0	0	3	0	0	0	6	0	0	0	9	0	0	0	12	0	0	0	15	0
10	0	0	3	4	0	0	6	8	0	0	10	0	9	6	13	4	0	0	16	8
11	0	0	3	8	0	0	7	4	0	0	11	0	0	0	14	8	0	0	18	4
12	0	0	4	0	0	0	8	0	0	0	12	0	0	0	16	0	0	0	20	0
13	0	0	4	4	0	0	8	8	9	0	13	0	0	0	17	4	0	0	21	8
14	0	0	4	8	0	0	9	4	0	0	14	0	0	0	18	8	0	0	23	4
15	0	0	5	0	0	0	10	0	0	0	15	0	0	0	20	0	0	0	25	0
16	0	0	5	4	0	0	10	8	0	0	16	0	0	0	21	4	0	0	26	8
17	0	0	5	8	0	0	11	4	0	0	17	0	0	0	22	8	0	0	28	4
18	0	0	6	0	0	0	12	0	0	0	18	0	0	0	24	0	0	0	30	0
19	0	0	6	4	0	0	12	8	0	0	19	0	0	0	25	4	0	0	31	8
20	0	0	6	8	0	0	13	4	0	0	20	0	0	0	26	8	0	0	33	4
21	0	0	7	0	0	0	14	0	0	0	21	0	0	0	28	0	0	0	35	0
22	0	0	7	4	0	0	14	8	0	0	22	0	0	0	29	4	0	0	36	8
23	0	0	7	8	0	0	15	4	0	0	23	0	0	0	30	8	0	0	38	4
24	0	0	8	0	0	0	16	0	0	0	24	0	0	0	32	0	0	0	40	0
25	0	0	8	4	0	0	16	8	0	0	25	0	0	0	33	4	0	0	41	8
26	0	0	8	8	0	0	17	4	0	0	26	0	0	0	34	8	0	0	43	4
27	0	0	9	0	0	0	18	0	0	0	27	0	0	0	36	0	0	0	45	0
28	0	0	9	4	0	0	18	8	0	0	28	0	0	0	37	4	0	0	46	8
29	0	0	9	8	0	0	19	4	0	0	29	0	0	0	38	8	0	0	48	4
30	0	0	10	0	0	0	20	0	0	0	30	0	0	0	40	0	0	0	50	0
31	0	0	10	4	0	0	20	8	0	0	31	0	0	0	41	4	0	0	51	8

Feet sup.	½ brick.				1 brick.				1½ brick.				2 bricks.				2½ bricks.			
	R.	Q.	F.	In.	R.	Q.	F.	In.	R.	Q.	F.	In.	R.	Q.	F.	In.	R.	Q.	F.	In.
32	0	0	10	8	0	0	21	4	0	0	32	0	0	0	42	8	0	0	53	4
33	0	0	11	0	0	0	22	0	0	0	33	0	0	0	44	0	0	0	55	0
34	0	0	11	4	0	0	22	8	0	0	34	0	0	0	45	4	0	0	56	8
35	0	0	11	8	0	0	23	4	0	0	35	0	0	0	46	8	0	0	58	4
36	0	0	12	0	0	0	24	0	0	0	36	0	0	0	48	0	0	0	60	0
37	0	0	12	4	0	0	24	8	0	0	37	0	0	0	49	4	0	0	61	8
38	0	0	12	8	0	0	25	4	0	0	38	0	0	0	50	8	0	0	63	4
39	0	0	13	0	0	0	26	0	0	0	39	0	0	0	52	0	0	0	65	0
40	0	0	13	4	0	0	26	8	0	0	40	0	0	0	53	4	0	0	66	8
41	0	0	13	8	0	0	27	4	0	0	41	0	0	0	54	8	0	1	0	4
42	0	0	14	0	0	0	28	0	0	0	42	0	0	0	56	0	0	1	2	0
43	0	0	14	4	0	0	28	8	0	0	43	0	0	0	57	4	0	1	3	8
44	0	0	14	8	0	0	29	4	0	0	44	0	0	0	58	8	0	1	5	4
45	0	0	15	0	0	0	30	0	0	0	45	0	0	0	60	0	0	1	7	0
46	0	0	15	4	0	0	30	8	0	0	46	0	0	0	61	4	0	1	8	8
47	0	0	15	8	0	0	31	4	0	0	47	0	0	0	62	8	0	1	10	4
48	0	0	16	0	0	0	32	0	0	0	48	0	0	0	64	0	0	1	12	0
49	0	0	16	4	0	0	32	8	0	0	49	0	0	0	65	4	0	1	13	8
50	0	0	16	8	0	0	33	4	0	0	50	0	0	0	66	8	0	1	15	4
60	0	0	20	0	0	0	40	0	0	0	60	0	0	1	12	0	0	1	32	0
70	0	0	23	4	0	0	46	8	0	1	2	0	0	1	25	4	0	1	48	8
80	0	0	26	8	0	0	53	4	0	1	12	0	0	1	38	8	0	1	65	4
90	0	0	30	0	0	0	60	0	0	1	22	0	0	1	52	0	0	2	14	0
100	0	0	33	4	0	0	66	8	0	1	32	0	0	1	65	4	0	2	30	8
200	0	0	66	8	0	1	65	4	0	2	64	0	0	3	62	8	1	0	61	4
300	0	1	32	0	0	2	64	0	1	0	28	0	1	1	60	0	1	3	24	0
400	0	1	65	4	0	3	62	8	1	1	60	0	1	3	57	4	2	1	54	8
500	0	2	30	8	1	0	61	4	1	3	24	0	2	1	54	8	3	0	17	4
600	0	2	64	0	1	1	60	0	2	0	56	0	2	3	52	0	3	2	48	0
700	0	3	29	4	1	2	58	8	2	2	20	0	3	1	49	4	4	1	10	8
800	0	3	62	8	1	3	57	4	2	3	52	0	3	3	46	8	4	3	41	4
900	1	0	28	0	2	0	56	0	3	1	16	0	4	1	44	0	5	2	4	0
1000	1	0	61	4	2	1	54	8	3	2	48	0	4	3	41	4	6	0	34	8
2000	2	1	54	8	4	3	41	4	7	1	28	0	9	3	14	8	12	1	1	4
3000	3	2	48	0	7	1	28	0	11	0	8	0	14	2	56	0	18	1	36	0
4000	4	3	41	4	9	3	14	8	14	2	56	0	19	2	29	4	24	2	2	8
5000	6	0	34	8	12	1	1	4	18	1	36	0	24	2	2	8	30	2	37	4
6000	7	1	28	0	14	2	56	0	22	0	16	0	29	1	44	0	36	3	4	0
7000	8	2	21	4	17	0	42	8	25	2	64	0	34	1	17	4	42	3	38	8
8000	9	3	14	8	19	2	29	4	29	1	44	0	39	0	58	8	49	0	5	4
9000	11	0	8	0	22	0	16	0	33	0	24	0	44	0	32	0	55	0	40	0
10000	12	1	1	4	24	2	2	8	36	3	4	0	49	0	5	4	61	1	6	8

The left-hand column contains the area of the wall in superficial feet; the adjacent columns the quantity, reduced to the standard thickness, according to the different thicknesses on the top.

Example. What is the quantity of reduced brick-work in a wall containing 4540 superficial feet, 2 bricks thick?

Divide the number as in the preceding table, into its component parts, say 4540 = 4000 + 500 + 40, then by the table.

	R.	Q.	F.	In.
4000 contains	19	2	29	4
500 . . .	2	1	54	8
40 . . .	0	0	53	4
	22	1	1	4

The same by rule.

```
        4540
           4 number of half bricks.
        ----
      3)18160(      R. Q. F. In. as above.
        ----
  272) 6053 + 4(22   1  1  4
        544
        ----
         613
         544
        ----
¼ of a rod 68) 69 (1
          68
          --
           1
```

TABLE III.

Shews the value of reduced brick-work per rod, calculated at the several prices of £3 5s. £3 10s. £3 15s. £4 0s. £4 5s. and £4 10s. per rod for mortar, labour, and scaffolding; and of bricks from £1 10s. to £3 0s. per thousand; allowing 4500 bricks to the rod.

Bricks per thousand.			Mortar and Labour 3l. 5s. per rod.			Mortar and Labour 3l. 10s. per rod.			Mortar and Labour 3l. 15s. per rod.			Mortar and Labour 4l. 0s. per rod.			Mortar and Labour 4l. 5s. per rod.			Mortar and Labour 4l. 10s. per rod.		
£.	s.	d.	£.	s.	d.	£.	s.	d.	£.	s.	d.	£.	s.	d.	£.	s.	d.	£.	s.	d.
1	10	0	10	0	0	10	5	0	10	10	0	10	15	0	11	0	0	11	5	0
1	12	0	10	9	0	10	14	0	10	19	0	11	4	0	11	9	0	11	14	0
1	14	0	10	18	0	11	3	0	11	8	0	11	13	0	11	18	0	12	3	0
1	16	0	11	7	0	11	12	0	11	17	0	12	2	0	12	7	0	12	12	0
1	18	0	11	16	0	12	1	0	12	6	0	12	11	0	12	16	0	13	1	0
2	0	0	12	5	0	12	10	0	12	15	0	13	0	0	13	5	0	13	10	0
2	2	0	12	14	0	12	19	0	13	4	0	13	9	0	13	14	0	13	19	0
2	4	0	13	3	0	13	8	0	13	13	0	13	18	0	14	3	0	14	8	0
2	6	0	13	12	0	13	17	0	14	2	0	14	7	0	14	12	0	14	17	0
2	8	0	14	1	0	14	6	0	14	11	0	14	16	0	15	1	0	15	6	0
2	10	0	14	10	0	14	15	0	15	0	0	15	5	0	15	10	0	15	15	0
2	12	0	14	19	0	15	4	0	15	9	0	15	14	0	15	19	0	16	4	0
2	14	0	15	8	0	15	13	0	15	18	0	16	3	0	16	8	0	16	13	0
2	16	0	15	17	0	16	2	0	16	7	0	16	12	0	16	17	0	17	2	0
2	18	0	16	6	0	16	11	0	16	16	0	17	1	0	17	6	0	17	11	0
3	0	0	16	15	0	17	0	0	17	5	0	17	10	0	17	15	0	18	0	0

Example. What is the price of a rod of brick-work, when the rate of bricks is £2 2s. per thousand, and the price of mortar £4 5s. per rod?

Look from the given column of bricks until you come under £4 5s. the given price of labour and mortar, and you will find £13 14s. the price of the rod.

CARPENTRY.

This branch of building comprises the art of employing timber in the construction of edifices.

The art of employing timber in building may be classed under two distinct branches, Carpentry and Joinery.

Carpentry comprehends the large and rough description of work, or that which is requisite in the construction and stability of an edifice; and *Joinery*, the fittings up and decorative work, so necessary to the completion of a building.

Carpentry is, in general, valued by the cubical foot; and joinery by the superficial foot.

The principal operations which timbers have to undergo, from the time of their arrival in the carpenter's yard to their final destination in an edifice, may be classed under two general heads; those which respect individual prices, and those which respect their dependence on others.

Under the former of these heads is the pit-saw, by means of which, whole pieces of timber are divided, and reduced into their respective sized scantlings.

The term *scantling* implies dimensions in breadth and thickness, without any regard to length.

Planing, is the operation by which wood is reduced to a smooth and uniform surface, by means of an instrument called a plane, which takes a thin shaving off the surface of the wood, as it is moved backwards and forwards in a straight line by the hands of the workmen. There are, however, other operations of the plane besides that of reducing timber to an uniform and smooth surface, termed *grooving*, *rebating*, and *moulding*.

Grooving is forming a channel on the surface of a piece of wood, by taking away so much of the solid as is of the shape and size of the groove required.

Rabating or *rebating*, is reducing a piece by taking away from the angles a prism of the shape and size of the rabate required, so as to form an internal angle, and generally a right angle. This operation is frequently required in constructing door cases, and the frames of casement windows: the rabate, or groove, being intended as a ledge for the door or casement to rest in.

The pieces being cut into their proper scantlings, the next operation is the joining them together.

In this department we shall treat first, of the most approved methods of lengthening beams, by what is termed scarfing, or joining them in pieces; secondly, of the strengthening of beams by trussing; thirdly, of the methods of joining two timbers at angles, in any given direction; and lastly, of the mode of connecting several timbers in order to complete the design, and to effect certain powers respectively required by each individual piece.

To lengthen a piece of timber implies the act of joining or fastening two distinct pieces, so that a part of the end of one shall lap upon the end of another, and the surfaces of both, being one continued plane, form a close joint, called by workmen a *scarf*. It is manifest, that two bodies, joined together and intended to act as one continued piece, in a state of tension, or compression, cannot, by any possible means, be so strong as either pieces taken separately. It, therefore, requires much attention, and careful discrimination, in the choice and selection of such methods as are the most applicable to the peculiar circumstances of the case. Every two pieces of timber joined in the manner thus described, and, indeed, in most other cases, require some force to compress them equally on each side, and more particularly when the pieces are light; for this purpose iron bolts are used, which act as a tie, and possess the same effect as two equal and opposite forces would have in compressing the beam on each side the joint: and as the cohesive power of iron is very great, the hole, which is made to receive the bolt, may be of such dimensions as will not, in the least degree, tend to diminish the strength of the timber. When wooden pins are used, the bore is larger, and the joints weaker; consequently the two pieces, thus connected, are not held together by any compression of the pin, but merely by the friction of the individual pieces.

No specific distance can be laid down for the length of the scarf, though, in general, it may be observed, that, a long scarf has but little effect in diminishing the cohesive strength of a compound piece of timber; on the contrary, it affords an opportunity of increasing the number of bolts.

Fig. 558 shows the method of joining two pieces of timber by means of a single step on each piece.

By this method more than one-half the power is lost; and this scarf is not calculated to resist the force of tension equal to a single piece sawed half through its thickness from the opposite side, at a distance equal to the length of the

scarf; by the application of straps, however, it may be made to resist a much greater force.

Fig. 559 represents a scarf with parallel joints, and a single table upon each piece.

In this the cohesive-strength is decreased in a greater degree than the preceding example, by the projection of the table; but this affords an opportunity of driving a wedge through the joint between the ends of the tables, and thereby forcing the abutting parts to a joint.

A scarf of this description to be longer than those which have no tables, and the transverse parts of the scarf, must be strapped and bolted.

Fig. 560 presents us with the same opportunity of wedging as before. In this figure, if the parts LM and NO be compressed together by bolts as firmly as if they were but one piece, and if the projection of the tables be equal to the transverse parts of the joints L and O, the loss of strength, compared with that of a solid piece, will be no more than what it would be at L and O.

Strapping across the transverse part of the joint is much the best and most effectual way of preventing the pieces from being drawn from each other, by the sliding of the longitudinal parts of the scarf, and, therefore, giving to the bolts an oblique position.

Fig. 561 is a scarf formed by several steps.

In this, if all the transverse parts of the steps be equal, and the longitudinal parts strongly compressed by bolts, the loss of strength will only be a fourth, compared to that of a solid piece, there being four transverse parts, that is, the part which the end of the steps is of the whole.

Fig. 562 is a scarf with a bevel joint, and equally as eligible for ordinary purposes as any in use.

Figs. 561 and 563. Scarfs intended for longer bearings than the preceding one.

Fig. 564 represents the method of constructing a compound timber, when two pieces are not of adequate length to allow them to lap, by means of a third piece joined to both by a double scarf, formed by several gradations or steps, the pieces abutting upon each other with the middle of the connecting piece over their abutment.

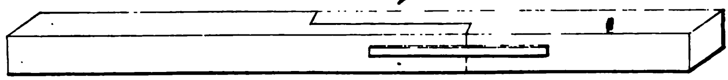
That which shall next claim our attention is a consideration of the principles and the best methods of strengthening beams by trussing.

When girders are extended beyond a certain length, they bend under their own weight, and the degree of curvature increases in a proportion far greater than that of their lengths. The best method to obviate this *sagging*, as it is

BUILDING

Plate 80 _ *From 558 to 566* _ Page 562.

558



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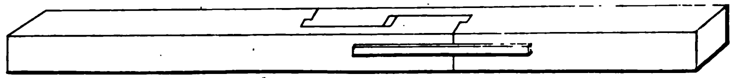

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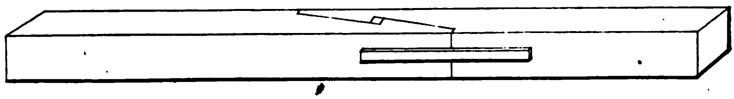

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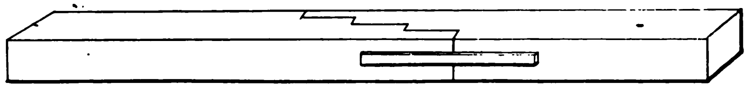

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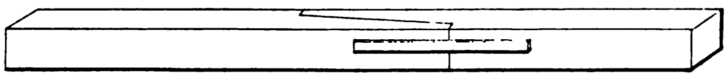

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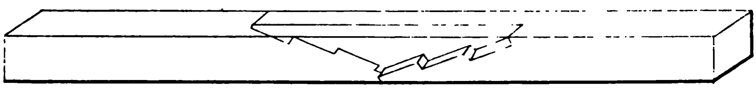

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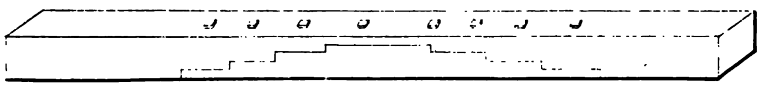

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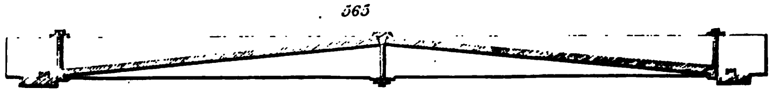

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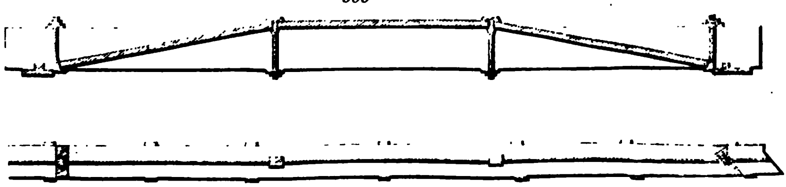


termed, without the support of posts, &c. is to make the beam in two equal lengths, and insert a truss, so that when the two pieces are confined together by bolts, the truss may be included between them, and cause them to act as a tie. To prevent any unfavourable results from natural tendency of the timbers to shrink, the posts of the truss may be made of iron, and screwed, and nutted at the ends; and to give a still stronger abutment, the braces may be let in with grooves into the side of each flitch, or piece, which form the beam. The ends of the abutments are also made of iron, screwed, or nutted, at each of the ends, and bolted through the thickness of both pieces, with a broad part in the middle, that the braces may abut upon the whole dimension of their section; or, otherwise, the abutments are made in the form of an inverted wedge at the bottom, and rise cylindrically to the top, where they are screwed and nutted.

These methods may be constructed either with one king-bolt in the middle, or with a truss-bolt at one-third of the length from each end. When two bolts are applied, they include a straining place in the middle. The two braces may be constructed of oak, or cast or wrought iron; but the latter material is seldom used: for, as all metals are liable to contract, wood is considered the best material. With respect to the bolts, iron is indispensable.

The higher the girder is, the less are the parts liable to be effected by the stress; and, consequently, the risk of their giving way under heavy weights, or through long bearings, is less.

Figs. 565 and 566 are two examples of girders calculated from their rise to sustain very heavy weights. If the tie beam be very strong, the abutments may be wedged; but the wedges ought to be very long, and a little taper, that there may be no inclination to rise. The excess of length may afterwards be taken off.

In joining two timbers together, in any given direction, the joinings, as practised by carpenters, are almost infinitely various; and though some are executed with a view merely to gratify the eye, the majority have decided advantages, and each, in peculiar cases, is to be preferred. In this treatise, our limits will not permit us to enter upon a description of such as yield no substantial benefit, or are employed only in connecting small work; but, even in these, the skill of the workman may at all times be discovered by his selection of materials. It may here be observed, that, as all timber is either more or less, according to the dryness,

and the quality of the timber used, subject to shrink, the carpenter should very carefully consider how much the dimensions of his framings will be affected by it, and so arrange the inferior pieces that their shrinkage shall be in the same direction as the shrinkage of the framing, and so conduce to the greater stability of the whole. If this be not attended to, the parts will separate and split asunder.

Two pieces of timber may be connected either by making both planes of contact parallel with or at right angles to the fibres, or by making the joint parallel with the fibres of the one piece, and at right or oblique angles to the other, or at oblique angles to the fibres of both pieces.

If two pieces of timber are connected, so that the joint runs parallel with the fibres of both, it is called a *longitudinal joint;* but when the place of the joint is at right angles to the fibres of both, an *abutting joint.* Butting and mitre joints are seldom used in carpentry.

When two pieces of timber are joined together at one or more angles, the one piece will meet the other and form one angle, or by crossing it make two angles, or the two pieces will cross each other and form four angles.

In all the following cases of connecting two timbers, it is supposed, that the sides of the pieces are parallel with the fibres, or, when the fibres are crooked, as nearly so as possible; and that each piece, the four sides being at right angles to each other, has at least one of its surfaces in the same plane with those of the other. The angle or angles so formed will be either right or obtuse.

Fig. 567, is an example of a notched joint, which is the most common and simple form, and, in some cases, the strongest for joining two timbers at one or more angles, particularly when bolted at the joint. The form of the joint may be varied, according to the position of the sides of the pieces, the number of angles, the quantity and direction of the stress on the one or both pieces, or by any combination of their circumstances. Notching admits two pieces to be joined at from one to four angles; but joining by mortise and tenon admits only from one to two angles.

In joining by mortise and tenon, four sides of the mortise should, if possible, be at right angles to each other, and to the surface whence it is recessed, and two of these sides parallel with each of the sides which forms a right angle with the side from which the mortise is made: the fifth plane, that is, the bottom of the mortise, is parallel with the top or surface from which the mortise is made. Four sides of the tenon should be parallel to the four sides of the piece; but there are many cases where a digression is unavoidable.

In the application of timbers to buildings, we will here suppose, that all pieces cut for use have a rectangular section, and when laid down, have their sides perpendicular to, and parallel with, the horizon. If two pieces of timber, therefore, are to be joined at four angles, cut a notch in one piece equal to the breadth of the other, so as to leave the remaining part of the thickness sufficiently strong, and insert the other piece in the notch ; or, if the work is required to be very firm, notch each piece reciprocally to each other's breadth, and fasten them together by pins, spikes, or bolts, as the case may require. This form is applicable when the pieces are equally exposed to a strain.

Fig. 568 will fully elucidate this description of joint.

The framing of timber by dove-tail notching is principally applicable to horizontal framing, where the lower timber is sufficiently supported. Where the lower timber is unsupported it is common to use mortise and tenon, which does not materially weaken the timber ; but when the timber is notched from the upper side, the operation reduces its thickness, and consequently impairs its strength, though, if the solid of one piece fill the excavation of the other, and both be lightly driven or forced together, according to Du Hamel, it will, if not cut more than one third through, rather increase than decrease in strength. It may, however, be observed, that in large works, where heavy timbers are employed, it is difficult, and almost impossible, to fit the mortise and tenon with due accuracy ; and even if the joints were closely fitted at first, the shrinking would occasion cavities on the sides, that would render the tenons of no avail, because the axis of fracture would be nearer to the breaking or underside of the supporting piece. What has been here said with respect to timbers placed horizontally, applies to framing in every position, when the force is to fall on the plane of the sides ; and if a number of pieces thus liable to lateral pressure on either side, are to be framed into two other stiff pieces, the mortise and tenon will prove best for the purpose.

If it be required to connect two pieces of timber so as to form two right angles, and to be immovable, when the transverse is held or fixed fast, and the standing piece pulled in a direction of its length, cut a dove-tail notch across the breadth of the transverse piece, and notch out the vertical sides of the standing piece at the end, so as to form a similar and equal solid. In some kinds of work, besides the dove-tail, an additional notch is cut to receive the shoulder

of the lower piece. If the position of these pieces be horizontal, and the upper is of sufficient weight, or is pressed down by any considerable force, when the pieces are placed together, the dove-tail will be sufficiently strong without the assistance of pins, spikes, or bolts. This construction requires the timbers to be well seasoned; for otherwise the shrinking will permit the standing piece to be drawn out of the transverse, and thus defeat the purpose of the construction.

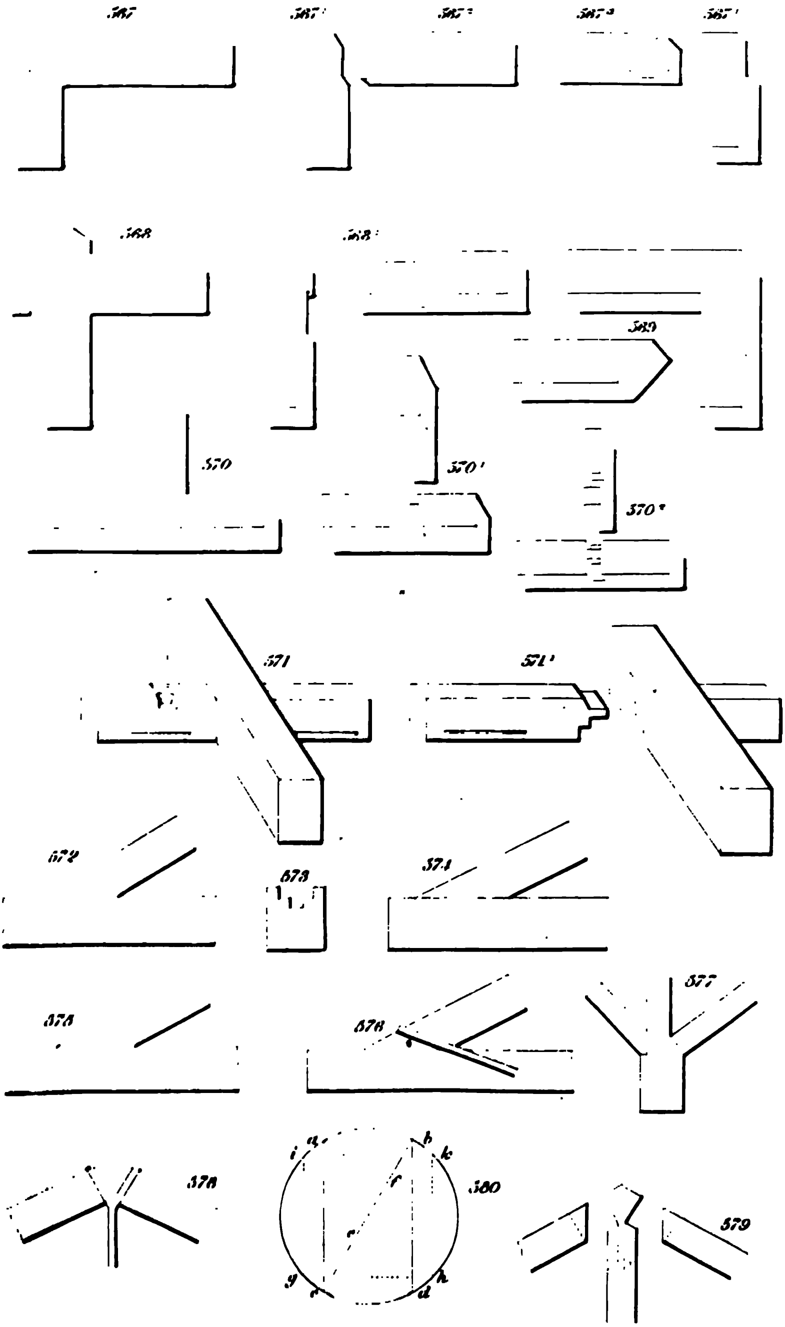
In introducing binding joists, which will, as they have to support the bridging joists and boarding of the floor, be framed into girders, there will be a considerable strain at the extremities, so that it is necessary, in order to make the tenons sufficiently strong, to have a shorter bearing tenon attached to the principal tenon, with a sloping shoulder above, called a *tusk*, which term is likewise applied to this tenon, called the *tusk tenon*.

When two parallel pieces, which are quite immovable, are to have another piece framed between them, the principle is, to insert the one end of the tenon of the piece to be framed in a shallow mortise, and make a long mortise in the opposite side of the other timber; so that when the cross piece is moved round the shoulder of the other extremity as a centre, it may slide home to its situation. This mode of framing a transverse piece between two others, is employed in trimming in ceiling joists, which joists are seldom or never cut and fitted into the binding joists before the building is covered over. The binding joists are always mortised before they are disposed in the situation to receive the ceiling joists.

When a transverse piece of timber is to be framed between two parallel joists, whose vertical surfaces are not parallel, turn the upper edge of the transverse piece downwards upon the upper horizontal surface of the joists, mark the interval, or distance between them, upon the surface of the transverse piece now under; then placing the edge over the place where it is intended to let down, turn the transverse piece in the way it is intended to be framed, apply a straight edge to the oblique surface of the joist, and slide the transverse piece so as to bring the mark on the upper side of it on a line with the straight edge, which being done, proceed in the same manner with the other end, and the two lines drawn on the vertical sides of the intermediate piece will give the shoulders of the tenons. This act of framing a transverse joist between two others is termed *tumbling in*

BUILDING

Plate 81._ From 367 to 380 _ Page 367.



joists; and is particularly useful when the timber is warped or twisted.

In order that the reader may the more fully understand the preceding description of the joinings of timbers, we have annexed a plate (to which the subjoined description refers,) of the best methods now in practice.

Fig. 457. No. 1 and 2, and 3 and 4, exhibit two methods of a simple joint, where the two pieces are halved upon each other; in both of which the end of one piece does not pass the outer surface of the other. No. 3 and 4 represent the two pieces before put together.

Fig. 568, is a method of joining timber, when the end of one piece passes the end of the other at a small distance. No. 1 represents the pieces before joined.

Fig. 569 shews how two pieces may be joined by what is termed a mitre.—In this case, the two pieces should be fixed to another by a bolt at right angles to the mitre joint.

Fig. 570. How one piece of timber may be joined to another, when one of the pieces is extended on both sides of the other piece. Nos. 1 and 2 show the pieces before put together.

Fig. 571 shows the manner of joining the binding joists and girders. No. 1. The binding joist prepared for being joined to the girder.

Fig. 572 is the general and most approved method of framing the rafter foot into the girder.

Fig. 573 is a section of the beam, shewing the different shoulders of the rafter foot.

Fig. 574 is another example, preferable to the former, because the abutment of the inner part is better supported. In this the beam, when no broader than the rafter is thick, may be weakened, in which case, it would require a much deeper socket than is here given; and perhaps an advantage would be gained by introducing a joint like fig. 575.

Fig. 576 is the method of introducing iron straps to confine the foot of the rafter to the tie-beam.

When it is found necessary to employ iron straps for strengthening a joint, considerable attention is required to place them properly. The first thing to be ascertained is the direction of the strain. We must then endeavour, as near as we can, to resolve this strain into a strain parallel to each piece, and another perpendicular to it. Then the strap which is to be made fast to any of the pieces, must be so fixed that it shall resist in the direction parallel to the piece.

The strap which is generally misplaced, is that which connects the foot of the rafter with the tie-beam. It binds down the rafter; but does not act against its horizontal thrust. It should be placed farther back on the beam, and have a bolt through it, to allow it to turn round; and should embrace the rafter almost horizontally near the foot, and be notched square with the back of the rafter. The example given in No. 10 combines these requisites. By

moving round the eye-bolt, it follows the rafter, and can not pinch and cripple it, which it always does in its ordinary form. Straps which have eye-bolts on the very angles, and allow motion round them, are considered the most perfect.

Fig. 577 exhibits two methods of connecting the struts of a roof, or partition, &c. with the king-post.

If the action of a piece of timber on another does not extend, but compress, the same, there is no difficulty whatever in the joint, indeed joining is unnecessary: it is enough that the pieces abut on each other; and we have only to take care that the mutual pressure be equally borne by all the parts, and that no lateral pressure, which may cause one of the pieces to slide on the butting joint, be produced. At the joggle of a king-post, a very slight mortise and tenon, with a rafter, or straining beam, is sufficient. It is generally best to make the butting plain, bisecting the angle formed by the sides, or else perpendicular to one of the pieces. For instance, the joint *a* is preferable to *b*, and, indeed, to any uneven joints, which never fail to produce very unequal pressures, by which some of the parts are crippled, and others splintered off.

Fig. 578 is the method of securing the tie-beam and principals, when the king-post is made of an iron rod.

Fig. 579 shows a method of joining the principals with the king-post by means of an iron dove-tail, which is received in a mortise at the head of each principal.

Trusting that the reader will be able, from the above description, to comprehend the best methods of joining timbers, we shall next proceed to describe the modes of connecting several timbers, in order to complete the design, and to effect certain powers respectively required by each individual piece.

In framing centres for groins, the boarding which forms the interior surface is supported by transverse ribs of timber, which are either constructed simply, or with trusses, according to the magnitude of the work; and, as a groin consists generally of two vaults intersecting each other, one of them is always boarded over the same as a plain vault, without any respect to the other, which is afterwards ribbed and boarded so as to make out the regular surface.

Timbers inserted in walls, and at returns, or angles, are joined together where the magnitude of the building or exposure to strain may require. There are three denominations, viz. *bond timber*, *lintels*, and *wall-plates*.

Flooring is supported by one or more rows of parallel beams, called *naked*, or *carcase flooring*, and is denominated either single or double. During the construction of the building, the flooring, if not supported by walls or partitions, must be shored. The framing of flooring, whether single or double, depends upon the magnitude of the building, the horizontal dimensions of the apartments, or the stress with which the surface of the boarding is likely to be affected. When the flooring is intended to be very stiff and firm, it is necessary to introduce truss girders. Naked flooring, for ball-rooms, should be framed very strong, and the upper part contrived with a spring, to bend with the impression of the force, while the lower part, which sustains the ceiling, remains immovable.

Partitions are constructed of a number of pieces of timber, called *scantling*, placed vertically, at a specified distance from each other, dependent on the purposes for which it is intended to answer. If to support girders, they should be trussed, and afterwards filled in with parallel pieces, called *studs*.

The framing ought to be so contrived, as to supersede the necessity of hanging up the floor, in whatever situation the doors may be placed. Truss partitions are also of the greatest utility in supporting floors which are above them.

The rafters which support the covering in a roof are sustained by one, two, or several pieces of framing, called a *pair of principals*, placed at right angles to the ridge of the roof. In roofing, many ingenious contrivances are resorted to, their application depending upon the pitch of the roof, the number of compartments into which it may be divided, and the introduction of tie-beams. In cases where apartments are required to be within the framing of the roof, and it is inconvenient to introduce tie-beams, the sides of the roof may be prevented from descending, by arching them with cast-iron, or trussing them with wood in the inclined planes of their sides. To restrain the pressure of the rafters, which would be discharged at the extremities of the building, a strong wall-plate, well connected in all its parts, must be introduced, to act as a tie, and prevent the lateral pressure from forcing out the walls.

In this construction, as well as in the former, the rafters would have a tendency to become hollow, so that it is necessary, in order to counteract this tendency, to introduce straining beams at convenient heights; and if it be requisite to occupy very little space by the wood-work, cast-iron

arches, abutting upon each other, and screwed with their planes upon the upper sides of the rafters, are best adapted for the purpose. If this and the former principle were adopted, the combined effect would be very great.

We shall now present the reader with a few practical observations.

Timber, except it stand perpendicular to the horizon, is much weakened by its own weight. The bending of timber is nearly in proportion to the weight laid on it. No beam ought to be trusted for any long time, with above one-third or one-fourth part of the weight it will absolutely carry; for experiments prove, that a far less weight will break a piece of timber when hung to it a considerable time, than is sufficient to break it when first applied.

The strain occasioned by pulling timber in the direction of its length, is called *tension*. It frequently occurs in roofs, and is therefore worthy of consideration.

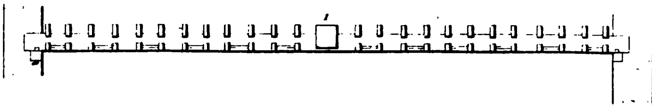
The absolute strength of a fibre, or small thread of timber, is the force by which every part of it is held together, and is equal to the force that would be required to pull it asunder. The force required to tear any number of threads asunder, is proportional to that of their sum; but the areas of the sections of two pieces of timber, composed of fibres of the same kind, are as the number of fibres in each; therefore, the strength of the timber is as the areas of the sections. Hence all prismatic bodies are equally strong; that is, they will not break in one part rather than in another.

Bodies which have unequal sections, will break at their smallest part; therefore if the absolute strength required to tear a square inch of each kind of timber be known, we shall be able to determine the strength of any other quantity whatever.

The wood next to the bark, commonly called *white* or *blea*, is also weaker than the rest: and the wood gradually increases in strength as we recede from the centre to the blea.

The heart of a tree is never in its centre, but always nearer to the north side, and on that side the annual coats of wood are thinner. In conformity to this, it is a general opinion among carpenters, that that timber is strongest whose annual plates are thickest. The *Tracheæ*, or *air-vessels*, are weaker than the simple ligneous fibres. These air-vessels make the separations between the annual plates, and are the same in diameter, and number of rows, in all trees of the same species; consequently, when these

Plate 82.— *From 581 to 583* — Page 571



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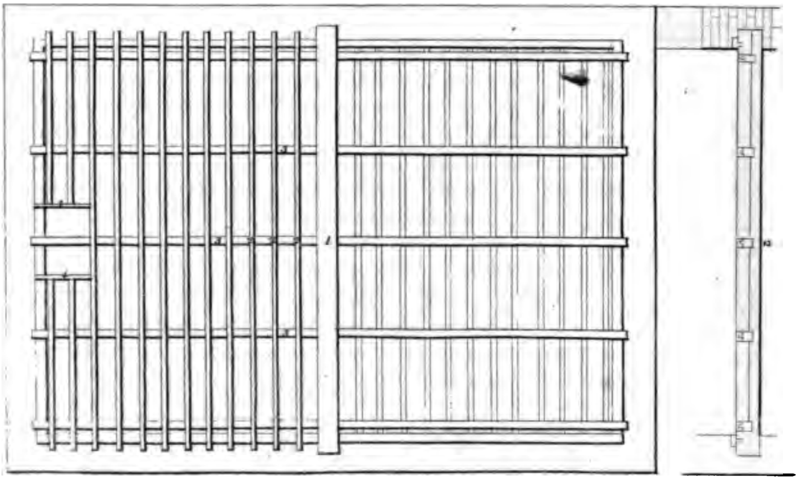

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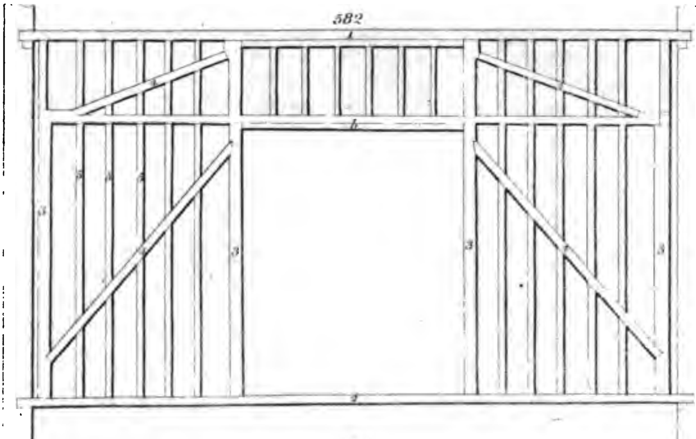

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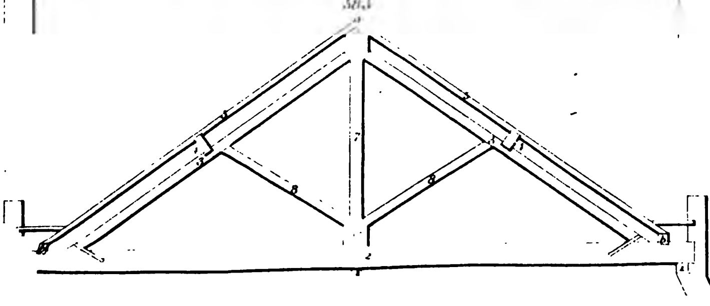

are thicker, they contain a greater proportion of the simple ligneous fibre.

The wood is stronger in the middle of the trunk than at the springing of the branches, or at the root; and the wood of the branches is weaker than that of the trunk.

The part of the tree towards the north, in the European climates, is the weakest, and that of the south side the strongest: and the difference is most remarkable in hedge-row trees, and such as grow singly.

All description of wood is more tenacious while green; and loses very considerably by drying, after the tree is felled.

We shall now conclude these remarks with the following useful problem.

Fig. 580. To cut the strongest beam possible out of a round tree whose section is a given circle. Let *a b c d* be the section of the tree; draw the diameter *c b*, divide it into three equal parts, *e* and *f*, and from one of them, as *f*, draw *f a* perpendicular to the diameter *c b*; draw *ab* and *a c*,—*b d* and *d c*, and *a b c d* is the strongest piece that can be cut out of the tree. From this it is manifest, that the strongest beam which can be cut out of a round tree, does not contain the most timber, for the greatest rectangle that can be inscribed in a circle is a square, and therefore the square *g h i k* is greater than the rectangle *a b c d*, and yet is not the strongest.

Fig. 581. Plan of a floor.—1. Girder resting upon the walls.—2. Bridging-joists.—3. Binding-joists.—4. Trimmers.

Nos. 1 and 2, sections of the floor.

Fig. 582. A trussed partition with an opening in the middle for folding doors.—1. Head.—2. Sill.—3. Posts.—4. Braces.—5. Studs.—6. Door-head.—This partition, as may be seen, supports itself.

Fig. 583. A simple trussed roof.

DEFINITIONS.

Wall-plates; pieces of timber laid on the wall, in order to distribute equally the pressure of the roof, and to bind the walls together. They are sometimes called *raising plates.*

Tie-beam; a horizontal piece of timber, connected to two opposite principal rafters; it answers a two-fold purpose, viz. that of preventing the walls from being pushed outwards by the weight of the covering, and of supporting the ceiling of the rooms below. When placed above the bottom of the rafters, it is called a *collar-beam.*

Principal rafters; two pieces of timber in the sides of the truss, supporting a grated frame of timber over them, on which the covering or slating rests.

Purlines; horizontal pieces of timber notched on the principal rafters.

Common rafters; pieces of timber of a small section, placed equidistantly upon the purlines, and parallel to the principal rafters: they support the boarding to which the slating is fixed.

Pole-plates; pieces of timber resting on the ends of the tie-beams, and supporting the lower ends of the common rafters.

King-post; an upright piece of timber in the middle of a truss, framed at the upper end into the principal rafters. and at the lower end into the tie-beam: this prevents the tie-beam from sinking in the middle.

Struts; oblique straining pieces, framed below into the king-posts, or queen-posts, and above into the principal rafters, which are supported by them; or sometimes they have their ends framed into beams, that are too long to support themselves without bending, they are often called *braces.*

Other pieces of timber are introduced in roofs of a greater span; which we shall here describe.

Queen-posts; two upright pieces of timber, framed below into the tie-beam, and above into the principal rafters; placed equidistantly from the middle of the truss, or its extremities.

Puncheons; short transverse pieces of timber, fixed between two others for supporting them equally; so that when any force operates on the one, the other resists it equally; and if one break the other will also break. These are sometimes called *studs.*

Straining-beam; a piece of timber placed between two others, called *queen-posts*, at their upper ends, in order to withstand the thrust of the principal rafters.

Straining-cill; a piece of timber placed upon the tie-beam at the bottom of two queen-posts, in order to withstand the force of the braces, which are acted upon by the weight of the covering.

Camber-beam; horizontal pieces of timber, made on the upper edge sloping from the middle towards each end in an obtuse angle, for discharging the water. They are placed above the straining-beam in a truncated roof, for fixing the boarding on which the lead is laid: their ends run three or four inches above the sloping plane of the common rafters, in order to form a roll for fixing the lead.

Auxiliary rafters; pieces of timber framed in the same vertical plane with the principal rafters, under, and parallel to them, for giving additional support. They are sometimes called *principal braces*, and sometimes *cushion rafters.*

Joggles; the joints at the meetings of struts, with king-posts, queen-posts, or principal rafters; or at the meeting of principal rafters with king and queen-posts: the best form is that which is at right angles to the struts.

Cocking, or Cogging; the particular manner of fixing the tie-beams to the wall-plates.

There are a variety of roofs differing in form, according to the nature of the plan, and the law of the horizontal and vertical sections.

The most simple form of a roof is that which has only one row of timbers arranged in an inclined plane, and throws the rain entirely on one side. This description of roof is termed a *shed-roof,* or *lean-to.*

If the plan of the roof be a trapezium, and the tops of the walls properly levelled, the roof cannot be executed in plane surfaces, so as to terminate in a level ridge; consequently, the sides, instead of being planes, are made to wind, in order to have the summit parallel to the horizon; but the best plan is, to make the sides of the roofs planes, enclosing a level space or flat, in the form of a triangle or trapezium, at the summit of the roof. Roofs which are flat on the top, are said to be *truncated:* they are chiefly employed with a view to diminish the height, so as not to predominate over that of the walls.

If all the four sides of the roof are formed by inclined planes, it is said to be *hipped,* and is therefore called a *hipped-roof;* and the inclined ridges, springing from the angles of the walls, are called *hips.*

Roofs on circular bases, with all their horizontal sections circular, the centres of the circles being in a straight line, from the centre of the base perpendicular to the horizon, are called *roofs of revolution* or *revolved-roofs.*

When the plan of the roof is a regular polygon, circle, or an ellipsis, the horizontal sections being all similar to the base, and the vertical section a portion of any curve, which is convex on the outside, the roof is called a *dome.*

In roofs of rectangular buildings, when a saving of expense is of consequence, instead of a lead flat, which must be covered with lead or copper, a valley is introduced, which makes the vertical section in the form of the letter M, or rather an inverted W; hence it has obtained the name of *an* M *roof.*

The *pitch* of a roof, or the angle which its inclined side forms with the horizon, is varied according to the climate and the nature of the covering.

The inhabitants of cold countries make their roofs very high; and those of warm countries, where it seldom rains or snows, very flat. But even in the same climate the pitch of the roof is greatly varied. Formerly the roofs were made very high, probably with the notion that the snow would slide off easier; but where there are parapets, a high roof is attended with very bad effects, as the snow slips down and stops the gutters, and an overflow of water is the consequence; besides, in heavy rains, the water descends with such velocity, that the pipes cannot convey it away soon enough to prevent the gutters from being overflowed.

The height of roofs at the present time is very rarely above one-third of the span, and should never be less than one-sixth. The most usual pitch for slates is that when the height is one-fourth of the span, or at an angle of $26\frac{1}{2}$ degrees with the horizon. Taking this as a standard, the following table will show the degree of inclination which may be given for other materials :—

Kind of covering.	Inclination to the horizon in degrees.		Height of roof in parts of Span.	Weight upon a square of roofing.	
	Deg.	Min.			
Copper or lead	3	50	$\frac{1}{48}$	copper lead	100 700
Slates large	22	0	$\frac{1}{5}$		1120
Ditto ordinary.	26	33	$\frac{1}{4}$	from to	900 500
Stone slate	29	41	$\frac{2}{7}$		2380
Plain tiles	29	41	$\frac{2}{7}$		1780
Pan-tiles	24	0	$\frac{2}{9}$		650
Thatch of straw, reeds.	45		$\frac{1}{2}$		

A roof for a span of from 20 to 30 feet may have a truss of the form shown in Fig. 583. Within this limit, the purlines do not become too wide apart, nor the points of support of the tie-beam.

For spans exceeding 30 feet, and not more than 45 feet, the truss shown in Fig. 584 is well adapted. Each purline is supported, consequently, there are no cross strains on the principal rafters; and the points of support divide the tie-beams into three comparatively short bearings. The sagging, which usually takes place from the shrinking of the heads of the queen-posts, may be avoided by letting the end of the principal rafter abut against the end of the straining

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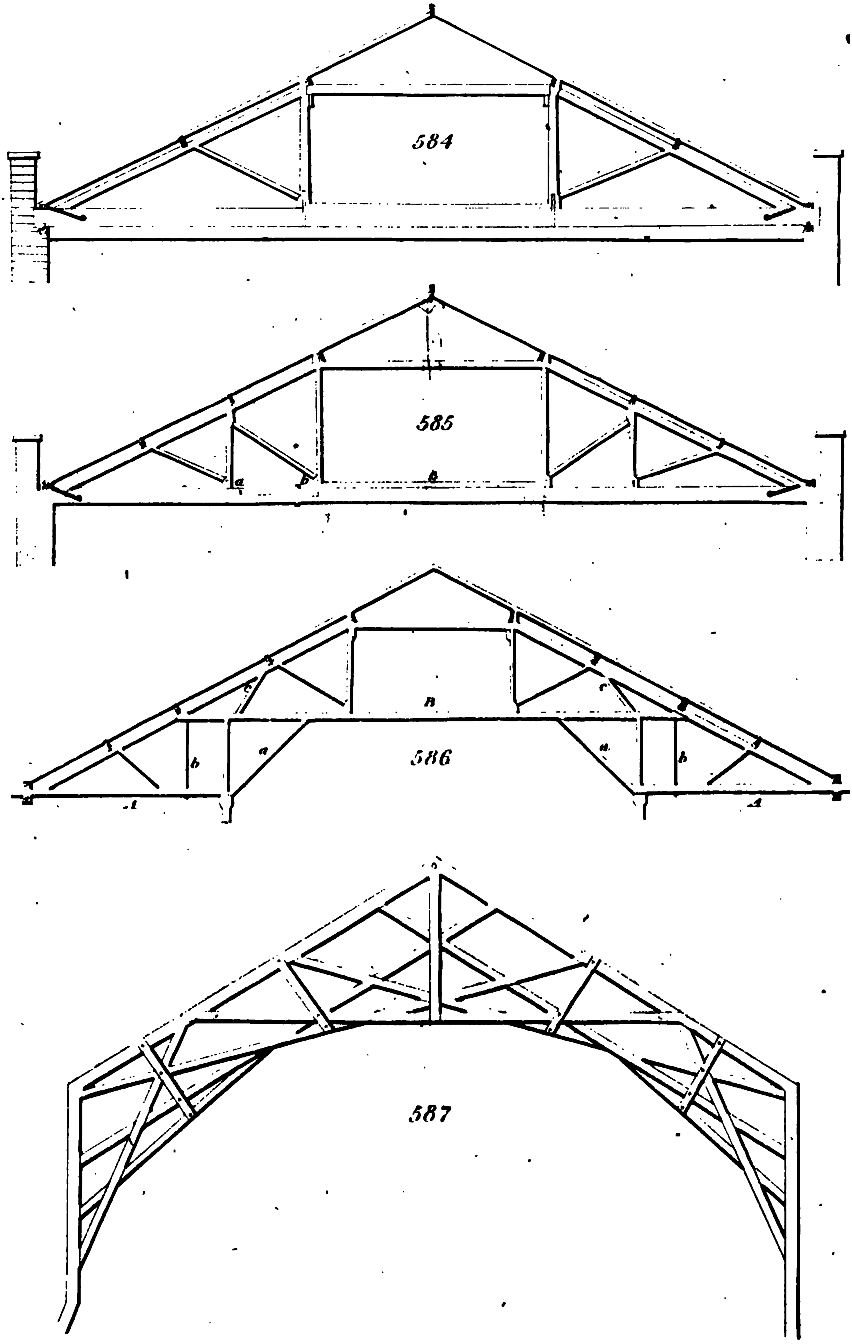
Plate 83. _ *From 584 to 587* _ Page 575.



beam A, and notching pieces and bolting them together in pairs at each joint.

When the span exceeds 45 feet, and is not more than 60 feet, the truss shown in Fig. 585 is sufficiently strong for the purpose, and leaves a considerable degree of free space in the middle. For this span the tie-beam will most likely require to be scarfed, and as the bearing of that portion of the tie-beam between *a* and *b* is short, the scarf should be made there. The middle part of the tie-beam may be made stronger by bolting the straining cill *c* to it.

It often occurs, that the centre aisles or naives of churches are higher than the side aisles; a similar effect, as when the tie-beam continues through, may be produced by connecting the lower beams to the upper one, by means of braces, so that the whole may be as a single beam. To illustrate this mode of construction, we have given a design for a roof of a church, somewhat similar to St. Martin's in the fields, London.

Fig. 586, the lower ties, AA, are so connected with the principal tie-beam, B, by means of the braces, *a*, *a*, that the foot of the principal rafters, *c*, *c*, cannot spread without stretching the tie-beam, B. The iron rods, *b*, *b*, perform the office of king-posts to the ties, A, A, and are much better than timber, in consequence of the shrinkage, which in this situation would be very objectionable.

Fig. 587 is a design for a roof of a church, or other building, requiring a semicircular arched ceiling.

Domes derive their names according to the plans on which they are built, circular, elliptical, or polygonal: of these, the circular may be spherical, spheroidal, ellipsoidal, hyperboloidal, paraboloidal, &c. Those which rise higher than the radius of the base, are called *surmounted domes*; those that are of a less height than the radius, *diminished*, or *surbased*; and such as have circular bases, *cupolas*. The most usual form for a dome is the spherical, in which case, the plan is a circle, and the section a segment of a circle.

The top of a large dome is often finished with a lantern, supported by the framing of the dome.

The interior and exterior forms of domes are seldom alike, and in the space between them, a staircase to the lantern is usually made. According to the space left between the external and internal domes, the framing must be designed. Sometimes the framing may be trussed with ties across the opening; but generally the interior dome rises so high that ties cannot be obtained.

Fig. 588, No. 1, shows the construction of a dome without ties. This is the most simple method, and one which is particularly applicable to domes of ordinary dimensions. This example consists in placing a num-

ber of curved ribs, so that the lower ends stand upon and are well framed into the kirb at the base, and the upper ends meet at the top, or are framed into the upper kirb on which the lantern is placed.

When it occurs, as it generally does, that the pieces are so long, and so much curved, that they cannot be cut out of timber without being cut across the grain, so much as will weaken them, they should be put together in thicknesses, with the joints crossed, and well bolted together.

No. 2, shows the ribs fixed, and bolted together, with horizontal rafters to receive the boarding on the exterior, and the laths on the interior. These ribs should be placed about two feet, or two feet six inches apart at the base, and be composed of three or four thicknesses of one and a half inch-deal, about 11 or 12 inches wide, which, when carefully bolted together with the joints judiciously broken, will stand exceedingly firm and well.

To construct the ribs of a spherical dome, with eight axal ribs, and one purline in the middle.

(Fig. 589.) No. 1. Let ABCDE be the plan of half the dome, which divide into four equal parts at BCD and E, these points of division will mark the centre of the back, or convex sides of the ribs. This being done, let B *b*, C *c*, D *d*, be the plans of these ribs, with the points of division in the centre. F, G, H, I, K, are the seats of the upper ends of the ribs; on the upper kirb draw *x y*, No. 2, parallel to AE, then from the different seats of the ribs on the plan draw perpendiculars cutting *x y*. Draw the cill, *x y*, its intended thickness, and complete the elevation of the front and back ribs. The front ribs are quadrants, forming a semicircle on the upper side of the wall-plate, which, of course, is the diameter. The curves of the sides of each of the other ribs are the quadrants of an ellipsis of the same height with the front rib. Place the purlines in their intended situation, and having drawn the elevation and plan, as shown by the dotted line, the construction is complete.

The ribs of an elliptical dome are found precisely on the same principle.

Given the plan of a polygonal dome, and one of the axal ribs, at right angles to one of the sides, to find the curve of the angle rib and the covering.

Fig. 590. Let A, B, C, D, E, F, G, H, be the plan of an octangular polygonal dome, and *c a b* the given rib; produce *c a* to *d*, divide the curve line *a* BA *b* into any number of equal parts, the more the better, in this case four, 1, 2, 3, *b*, which extend on the line *a d*; the first from *a* to 1, the second from 1 to 2, &c.: from the points of division, 1, 2, 3, *b*, draw lines parallel to B *e*, cutting C *c*, and from these points draw lines, parallel to *c d*, or at right angles to B *e*, and through the points, 1, 2, 3, draw *k l*, *m n*, *o p*, and tracing a curve through the points *d*, *p*, *n*, *l* C, and making *d o m k* B similar, then the space comprehended between the curve lines *d* B *e*; and the side BC of the plan, will give the form of the whole covering, for each side of the dome.

To find the hip-line of the angle-rib, whose base is C *c*.

Draw CE, 2 *e*, 1 *f*, at right angles to C *c*, and make CE equal to *c b*,

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Plate 84._*From 588 to 594*_Page 576.

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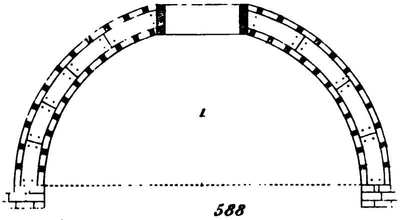

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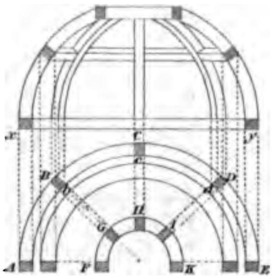

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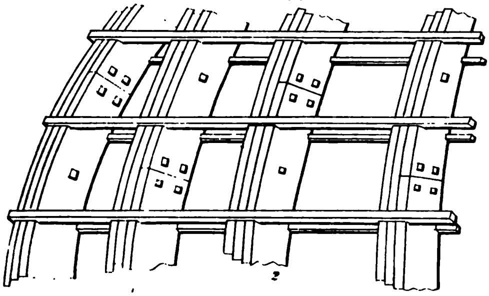

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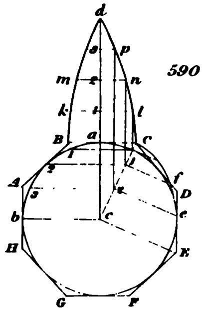

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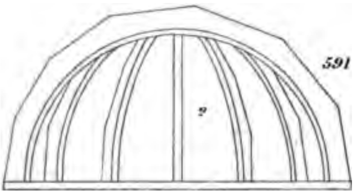

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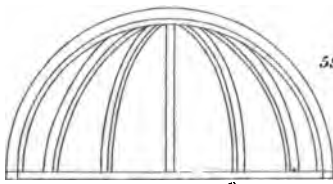

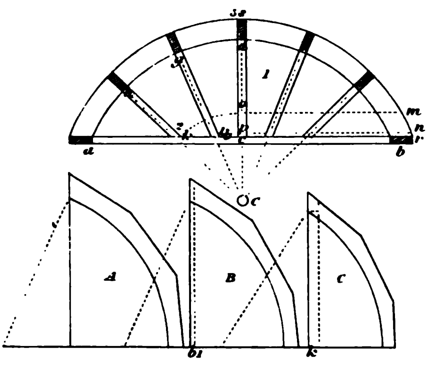

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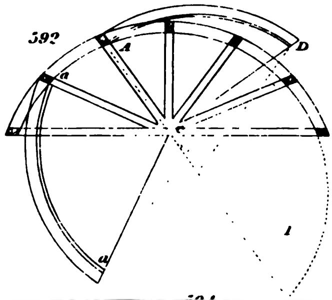

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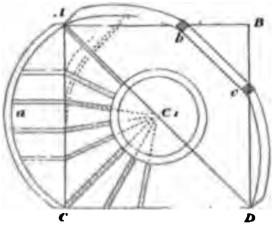

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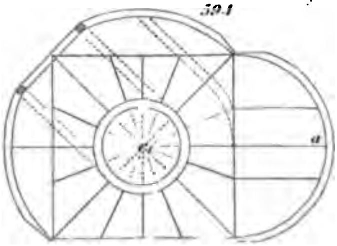

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2 *e* equal 2-3, and 1 *f* equal to 1, 2, &c. and trace the curve through these points, and it will give the angle-rib.

The method of covering spherical domes is, to suppose them polygonal, and the principle the same as the foregoing operation for an octangular dome.

A *niche*, in carpentry, is the wood-work to be lathed over for plastering. The general construction of niches is with cylindrical backs and spherical heads, called *cylindro-spheric niches*; the execution of which depends upon the principles of spheric sections.

As every section in a sphere is a circle, and that section passing through its centre is equal, and the greatest that can be formed by cutting the sphere; it is evident, that if the head of a niche is intended to form a spherical surface, the ribs may be all formed by one mould, whose curvature must be equal to that of the greatest circle of the sphere; viz. one passing through its centre; but the same spherical surface may, though not so eligible, be formed by ribs of wood, moulded from the sections of lesser circles, in a variety of ways.

The reason why these latter spherical surfaces are not so eligible as those of greater circles is, because their disposition for sustaining the lath is not so good, and the trouble of moulding them to different circles, and of forming the edges according to different bevels, in order to range them in the spherical surface, is very great, compared with those made from great circles.

The disposition of the ribs of niches is generally in a vertical plane, parallel to each other, or intersecting each other in a vertical line. When the line of intersection passes through the centre of a sphere, all the ribs are great circles; but if the line of intersection does not pass through the centre of the sphere, the circles which form the spherical surface are all of different radii. When the ribs are fixed in parallel vertical planes, their disposition is either parallel to the face of the wall, or parallel to a vertical plane, passing through the centre of the sphere, perpendicular to the surface of the wall; but this method is not so eligible for the purposes of lathing.

Another method is, by making the planes of the ribs parallel to the horizon: this is not only attended with great labour in workmanship, but is incommodious for lathing. The various positions in which the ribs of a niche may be placed, are very numerous; but the regular positions, al-

ready enumerated, ought to be those to which the carpenter should direct his attention.

To get out the ribs for the head of a niche, all of them being in vertical planes passing through the centre of the sphere.

Fig. 591, No. 1. From the centre C draw the ground-plan of the ribs, and set out as many ribs upon the plan as you intend to have in the head of the niche. With the foot of your compasses in C, and from the ends of each rib, at *k* and *l*, draw the small concentric dotted circles round to the centre rib, at *o* and *p*, and draw *o m*, and *p n*, parallel to *a b*, the face of the wall; then from *r* round to *s* on the plan is the length and sweep of the centre rib to stand over; and from *n* round to *s* the length and curve of the rib that stands from *b* to *g*; and from *m* round to *s*, the curve of the shortest rib, that stands from *k* to *h* on the plan.

How to find the bevel of the ends of the back ribs against the front rib.

The back ribs are laid down distinct by themselves, at AB and C from the plan. Take *b* 1, in No. 1, and set it to *b* 1, at B, draw the perpendiculars, and when they intersect the rib, it will show the bevel required. The same operation being done to C, the bevel is found in the same manner.

The places of the back-ribs when fixed upon the front-rib are ascertained by drawing perpenuculars, and completing the elevation of the niche No. 2 from the plan.

To find the radius of curvature of the ribs of a spherical niche, when the ribs all meet in a vertical line, which divides the front rib into two equal parts.

Fig. 592, No. 1. Complete the circle, of which the inside of the plan is an arc; produce the middle line of the plan of any rib, as of *a b*, to meet the opposite side of the circumference in *b*; on the whole line *a b*, as a diameter, describe a semicircle, and from the point *c*, when the ribs intersect, draw *a* perpendicular to *c d*, to meet the arc *a d* at *d*, which arc is the curve of the rib, whose seat is *d*. The other rib, as AD, is found in the same manner. No. 2 is the elevation of the niche.

Pendentive cradling, is a cove bracketing, springing from the rectangular walls of an apartment upwards to the ceiling, so as to form the horizontal part of the ceiling into a complete circle or ellipsis.

The proper criterion for such bracketing, if the walls are cut by horizontal planes through the coved parts, is, that all the sections through such parts will be portions of circles, or of ellipses, and have their arcs proportioned to the sides of the apartment, so that each section will be a compound figure. Besides having four curvilinear parts, it will have four other parts, which are portions of the sides of the rectangular apartment: and the axis of the ellipsis will bisect each side of the rectangle.

Fig. 593. Let ABCD be the plan of a room, or stair-case, to be brack-

eted, so as to form the surface of a pendentive ceiling; and let A *b* *c* D be the section across the diagonal; it is required to find the curvature of the springing ribs?

Draw C *d* perpendicular to AC, meeting AC, take the distance from C to the line AC, and set it from C on the line CA, and from this point draw a perpendicular to meet the curve A *l* *e* D of the diagonal rib; make the versid sine of the segment A *d* C equal to this perpendicular, and describe the segment A *d* C, which is the springing line required. If from the centre C an arc be described, with a radius equal to the length of the seat of a rib, to meet the seat of the diagonal rib AD; and, if from the point of meeting a perpendicular be drawn to meet the curve A *b*, the portion of the arc of the diagonal rib, intercepted between A and the perpendicular, will give the length of the rib, corresponding to the seat which was taken.

Fig. 594. The diagonal rib is a semicircle: the operation is exactly the same, and may be described in the same words.

MENSURATION OF CARPENTERS' WORK.

All large and plain articles in which an uniform quantity of materials and workmanship is expended, are generally measured by the square of 100 superficial feet.

Piles used in the foundations are valued at per piece, and driven by the foot run, according to their diameter, and the quality of the ground.

Keepers and planking are measured by taking the superficial contents in yards or squares.

Plain centreing is measured by the square; but as the ribs and boarding are two different qualities of work, they ought to be measured and valued separately; one dimension of the boarding being taken by girting it round the arch, the other being the length of the vault.

Centreing for groins should be measured and valued as common centreing; but in addition thereto, the angles should be paid for by the foot run, that is, the ribs and boarding ought to be measured and valued separately, according to the exact superficial contents of each; and the angles by the lineal foot for workmanship, in fitting the rib and boards, and for the waste of wood occasioned by the operation.

Wall-plates, lintels, and bond-timbers, are measured by the cubic foot, under the denomination of fir-in-bond.

Naked flooring may either be measured by the square, or by the cubic foot, according to the description of the work, and the quantity of timber employed. In forming an estimate of its value, it should be observed, that in equal cubic quantities of small and large timbers, the small tim

bers will have more superficies than the large ones, and, therefore, the saving will not be in a ratio with the solid contents; consequently the value of the workmanship will not follow the cubic quantity, or said ratio. The difficulty of handling timbers of the same length increases with the weight or solidity, as the greater quantity requires greater power to handle it, and consequently more time.

In naked flooring, where girders are introduced, the uniformity of the work is interrupted by mortises and tenons, so that the sum ascertained by the cubic quantity of the girders, at the same rate per foot as the other parts, is not sufficient; not only on account of the great difference of size, but the great disparity in the quantity of workmanship, occasioned by its being cut full of mortises to receive the tenons of the binding-joists; the best method, therefore, to value the labour and materials is, to measure and estimate the whole by the cubic quantity, and allow an additional rate upon every solid foot of girders; or, if the binding-joists are not inserted in the girders, at the usual distances, a fixed price for every mortise and tenon, in proportion to their size, which will keep a ratio with the area of the end of the girder.

Partitions may be measured by the cubic feet; but the cills, top-pieces, and door-heads, should be measured by themselves, according to the solid quantity, at an additional rate; because, both the uniform solidity, and the uniform quantity of workmanship are interrupted by them. In trussed partitions, the braces should be rated by the foot cube, at a superior price to that of the quarterings, for the trouble of fitting the ends of the uprights upon their upper and lower sides, and for forming the abutments at the ends.

The timbers in roofing should be measured by the cubic foot, classed as the difficulty of execution, or as the waste occasioned, may require.

Battening to walls is best measured by the square, according to the dimensions and distances in the clear of the battening.

It would be endless to enumerate the various methods of measuring each particular species of carpenters' work; the leading articles only need be noticed.

When the shell of a building is finished, that is, previous to the floors being laid, or the ceilings lathed, all the timbers should be measured, that no doubt may arise as to the actual scantlings of the timbers, or of the description of the workmanship. In taking dimensions it must be observed that,

all pieces which have tenons, must be measured to the extremities of the tenons.

It is impossible to determine on any proper rate, including both materials and workmanship, as the one may be stationary, while the other is variable. With respect to materials, the value of any quantity may be easily ascertained, whatever be the price per load ; but the difficulty is far greater in fixing proper rates of workmanship ; however, were the time of executing every species of work known, there would be no difficulty in establishing certain uniform quantities, which would give the real value.

JOINERY.

Is the next branch of art which comes under our consideration, and comprises the practice of employing wood in the external and internal finishings of houses.

In the execution of this branch of building, it is almost unnecessary to observe that, as joinery is employed principally by way of decoration, and is liable to close inspection, it is one of the departments which demands the strictest care and attention in the workmen; and it requires the greatest ingenuity, skill, and experience, to become fully master of every subject under the joiner's consideration.

The first and most important thing to be attended to, is the judicious selection of materials ; as, without a strict observance of this particular, the care, ingenuity, and exertions of the workman will be wholly frustrated.

As the temperature of the atmosphere has a great influence on wood, and more particularly in the winter season, it would be advisable to put that which is to be used in fine work over an oven for a day or two. In the different descriptions of joint used by the joiner, a hot tenacious liquid, called *glue*, is almost universally used, and when applied, the two surfaces of the wood, which have been previously rendered smooth, are rubbed together until the glue is nearly all forced out. One piece is then set to its situation with respect to the other.

For outside work, such as gates, doors, &c. white-lead is used in all the joints.

When a frame, consisting of several pieces, is required, the mortises and tenons are fitted together, and the joints glued all at one time, then entered to their places, and forced together by the assistance of an instrument called a *cramp*.

The operation of rendering a rough surface smooth, by taking away the superfluous wood, is called *planing;* and the tools used for this purpose are called *planes.*

The planes used by joiners in the primary operation of their work are called *jack-planes, trying-planes, long-planes,* and *smoothing-planes ;* the respective uses of which are as follow :—The jack-plane is used for taking away the rough occasioned by the saw, and removing all superfluous and other uneven parts. The trying-plane more particularly to bring the surface perfectly level and true : the long plane succeeds, when the surface is long, and is required to be very straight, as in jointing long boards for the purpose of gluing them together; and the smoothing-plane is used to smooth and clean off the work.

In addition to the above, termed *bench-planes,* others are occasionally used in forming any kind of prismatic surfaces, viz. *rebating-planes, grooving-planes, moulding-planes,* &c.; under which head is included the *fillister* and *plough.*

Rebating-planes are used for cutting out rebates, a kind of half groove, upon the edge of a board, or other piece of wood, formed by taking down or reducing a small part of the breadth of the board to half, more or less, of the general thickness. By this means, if a rebate be cut on the upper side of one board, and the lower side of another, the two may be made to overlap each other, without making them any thicker at the joint.

Rebates are also used for ornamenting mouldings, and for many other purposes in joiners' work. The planes for cutting them are of different kinds, some having the cutting edge at the side of the iron and stock ; others at the bottom edge of the iron and the face of the stock ; and others cutting in both these directions. The former are used to smooth the side of a rebate, and therefore are called *side rebating-planes* ; the others for smoothing the bottom. A third sort of rebate-planes, called a *fillister,* is used for sinking or cutting away the edge of a piece of wood, to form the rebate, leaving it for the others to smooth the surfaces when cut.

The *moving fillister* is a rebating-plane having a ruler of wood, called the *fence,* fixed by screws, upon its face, in the direction of its length, and exactly parallel to the edge of the face; consequently, it covers part of the width of the cutting edge, and can be fixed at any required distance from the edge, to leave more or less of the cutting edge exposed, which will be the breadth of the rebate it will cut, because,

when used, the edge of the fence is applied against the edge of the piece to be rebated, and thus gauges the breadth its iron should cut away. The cutting-iron of this plane is not situated at right angles to the length of the stock, but has an obliquity of about forty-five degrees; the exposed side of the iron being more forward than the one next to the fence. By this obliquity, the plane has a tendency or drift to run further into the breadth of the wood; but as the fence sliding against the edge prevents this, the drift always keeps the fence in contact with the piece without the attention of the workman: it also causes the iron to cut the bottom of the rebate smoother, particularly in a transverse direction to the fibres, or where the wood is cross-grained, or where the edge is perpendicular to the sides of the plane. It is chiefly used, however, to throw the shaving into a cylindrical form, and thereby make it issue from one side of the plane. Besides this iron, there is another of smaller dimensions, called the *tooth*, which precedes the other, to scratch or cut a deep crack in the width of the rebate, thus making the shaving, which the iron cuts up from the bottom, separate sideways from the rest of the wood. The *sash-fillister* differs in many particulars from the moving fillister: the fence is adapted to be moved to a considerable distance, not being fixed, as in the moving fillister, by screws upon the face, but sustained by two bars, fixed fast to it, passing through the two vertical sides of the stock at right angles to the sides: these bars, when set to their intended places, are tightened by small wedges. This kind of plane is usually employed to rebate narrow pieces of wood, such as are used in sashes; and the fence is applied against the opposite edge to that on which the rebate is to be formed.

The *plough* is a plane with a very narrow face, made of iron, fixed beneath a wooden stock, and projecting down from the wood of the stock; the edge of the cutting-iron being the full width of the groove required: it is guided by a fence with bars like the sash-fillister, and has also a stop to regulate the depth intended for the grooves.

Moulding-planes are those which have their faces and cutting edges curved, to produce all the varieties of ornamental mouldings: they are known by the names of ***snipe's-bills, side rebates, beads, hollows, rounds, ovolos,*** and *ogees*. Of these there are a great variety of sizes, with which every good joiner is furnished.

The whole of these planes have their faces straight in the

direction of their length; but a section across the face is the impression or reverse of the moulding they are intended to make.

The tools employed in boring cylindric holes are a *stock* with *bits*, *gimlets*, and *brad-awls* of various descriptions and sizes. The tools used for paring the wood obliquely, or across the fibres, and for cutting rectangular prismatic cavities, are in general denominated *chisels;* those for paring the wood across the fibres being called *firmers*, or *paring-chisels*, and those for cutting mortises, *mortise-chisels*. The best paring-chisels are made entirely of cast steel. Chisels for paring concave surfaces, are called *gouges*.

Wood is generally divided or reduced by means of *saws*, of which there are several sorts; as the *ripping-saw*, for dividing boards into separate pieces, in the direction of the fibres; the *hand-saw*, for cross-cutting, or for sawing thin pieces in the direction of their length; the *panel-saw*, either for cross cutting, or cutting very thin boards longitudinally; the *tenon-saw*, with a thick iron back, for making an incision of any depth below the surface of the wood, and for cutting pieces opposed to the length of the fibres; also a *sash-saw*, and a *dovetail-saw*, used much in the same way as the tenon-saw.

From the thinness of the plates of these three last-mentioned saws, it is necessary to stiffen them by a strong piece of metal called the back, which is grooved to receive the upper edge of the plate, fixed to the back, and which is thereby secured and prevented from crippling.

When it is required to divide boards into curved surfaces, a very narrow saw without a back, called a *compass-saw*, is used; and in cutting a very small hole, a saw of a similar description is used, called a *key-hole-saw*. Both of these description of saws are called *turning-saws*, and have their plates thin and narrow towards their bottoms, and each succeeding tooth finer.

The external and internal angles of the teeth of all saws are generally formed at one angle of 60 degrees, and the front edge teeth slope backwards in a small degree. The teeth of every description of saw, except turning-saws, are alternately bent on contrary sides of the plate, so that all the teeth on the same side are alike bent throughout the length of the plate, for the purpose of clearing the sides of the cut made by it in the wood. The foregoing are generally termed *edge-tools*.

When it is necessary to ascertain if an angle be exactly

square, or inclined to any number of degrees, a tool called a *square* is used, and in the latter instance, a *bevel* is set to the angle; when any piece is to be reduced to a parallel breadth or thickness, an instrument, called a *gauge*, formed of a square piece with a mortise, having a sliding bar, called a *stem*, running through it at right angles, and furnished with a tooth, projecting a little from the surface, is used; so that when the stock of the gauge is applied to the vertical side or edge of the piece, with the toothed side of the stem upon the horizontal surface, and is pushed and drawn alternately backwards and forwards by the workman, the tooth will make an incision from the surface into the wood, at a parallel distance from the edge to which the stock part is applied.

When a mortise is to be made in a piece of wood, the gauge used has two teeth. The construction of this gauge is the same as that before described, except that the tooth nearest the stock moves by means of a longitudinal slider in the stem, which is to be set at a distance from the other tooth, as occasion may require.

If a piece of wood is to be sawn across the fibres, a flat piece of wood, which has two projecting knobs, on opposite sides, one at each end, called a *side-hook*, is used, to keep the piece which has to undergo the operation of the saw steady; the knob at one end presses against the piece, while that at the other end is hooked to the bench. Two of these are necessary when the pieces are long.

When a piece of wood is required to be cut to a mitre, that is, to half a right angle, joiners use a trunk of wood with three sides, like a box that has neither ends nor top, the sides and bottom being parallel pieces, and the sides of equal height. Through each of the opposite sides, in a plane perpendicular to the bottom, and at the oblique angles of 45° and 135° with the planes of the sides, a kerf is cut; and another kerf is made with its plane at right angles to the two former. Into this trunk, termed a *mitre-box*, the piece to be cut is put, and the saw, guided by the kerfs, cuts the wood to the angle required.

In making a straight surface, a strip of wood called a *straight-edge*, which has one of its edges perfectly straight, is frequently applied, to detect the irregularities, and the piece is accordingly planed with the trying plane until the surface coincides with the straight-edge.

To ascertain if the surface of a piece of wood be in one plane, the joiner takes two slips of wood, each straightened

on one edge, with the opposite edge parallel, and both pieces of the same height, and places them one at each end, across the board under operation; he then looks in the longitudinal direction of the board over the upper edges of the slips, and if the two edges and his eye be not in one plane, the upper parts are planed down until the piece is said to be *out of wind*, and the same term is applied to the slips, which are called *winding-sticks*. The operation of making the edge of a board straight is called *shooting;* and the edge so made is said to be *shot.*

From what has been here said of the application of the principal tools used by the joiner, we consider any further account of the primary processes unnecessary; we shall, therefore, proceed to lay before the reader the best methods in use of effecting some of the more difficult and particular operations.

To construct the surface of a portion of a cylinder with wood, when the fibres are at right angles to the axis of the cylinder, such as may be used in a circular dado, or the soffits of windows.

If the dimension of the cylindric surface, parallel to the axis, be not broader than a plank or board, this may be done by gluing several thicknesses of veneer upon each other; the first upon a mould, or upon brackets, with their edges in the surface of the proposed cylinder, parallel to its axis. This may be effected by means of two sets of brackets fastened to a board, one convex and of the curve intended, and the other concave of the curve of the exterior of the whole thickness of veneers, or somewhat larger; this last bracket is then applied on the top of the veneers and fastened to the other bracket, and the veneers are then forced together by means of wedges between the concave bracket and the veneer. If this operation be carefully done and the glue properly dried, the wedges may be slackened and the work will stand well, but it must be observed, that, as the wood has a natural tendency to unbend itself, the curved surface, upon which it is glued, should be rather quicker than that intended to be made.

A *second* plan is to form a templet or cradle to the surface intended, and lay a veneer upon it; then to glue a number of blocks of wood upon its back, closely fitted to its surface, and the other joints to each other, the fibres of the veneer being parallel to those of the blocks.

A *third* method is to make a cradle and place the veneer upon it, confining one end: lay the glue between the

veneers with a brush, and fix a bridle across, confining its ends either by nails or by screws; open the veneers again, put glue a second time between each, and fix another bridle across them; and in this manner proceed to the other extremity.

A *fourth* plan is to cut a number of equidistant grooves across the back of the board, at right angles to its edges, leaving only a small thickness towards the face; then to bend this round a cradle with the grooves outwards, and fill the grooves with strips of wood, which, after the glue is quite dry, must be planed down level with the surface of the board. This may be stiffened by gluing strong canvass on the back.

To bend a board so as to form the frustum of a cone, or any segmental portion of the frustum of a cone, as the soffit of the head of an aperture.

When the envelope of the covering is found by the rule laid down under the article Masonry, page 542, and the mould is made with a thin piece of board, cut out the board intended to be bent, and run a number of saw kerfs, or grooves made by a plane, (which are preferable,) equidistant from each other, and tending to the centre, and having fixed it to a templet, made to the surface of a cone, finish it in the manner shown in the last method, for a cylinder.

To glue up the shaft of a column, supposing it to be the frustum of a cone.

Prepare as many staves as the circumference may require, and let the joints of each be so managed as to fall in the fillets, which disposition will be stronger than if they were to fall in the middle of the flutes. Suppose eight pieces to be sufficient to constitute the shaft of a column: describe a circle to the diameter of each end; about each circle describe an octagon; from the concourse of each angle draw a line to the centre, then draw an interior concentric octagon, with each side parallel to the respective sides of the corresponding one, and the distance between these two octagons equal to the thickness of the staves; and thus the section of the staves will be found at each end, and consequently, the bevels will be obtained throughout the whole length. In order to join the column, glue two pieces together, and when quite dry, glue in blockings to strengthen them; join a third piece to the former two, and secure it also by blockings. In this manner proceed to ast piece but one. In fixing the last ce, the blocki e glued to the adjacent staves;

and their surfaces, on which the last stave is intended to rest, must be all in the same plane, that its back may rest firmly upon them. In closing up the remaining space, the part of the column that is glued together should be kept from spreading by confining it in a kind of cramp, or cradle, while driving the remaining stave to close the joints.

Instead of the foregoing mode, some joiners glue up the columns in halves and then glue them together. When an iron core is necessary to support a floor or roof, the column must necessarily be glued up in halves; in which case the two halves are to be dowelled together, and the joints filled with white-lead. Instead of a cramp, a rope is used, twisted by means of a lever. In bringing the two halves together, the percussive force of the mallet must be applied upon the middle of the surface of one half, while an assistant holds something steady against the middle of the other, that the opposition may be equal, and by this means the surfaces will be brought into contact, and form the joint as desired. In this operation pieces of wood ought to be inserted between the column and the rope.

Boards can be connected together at any given angle, either by pins or nails, mortise and tenon, or by indenting them together.

This last mode, from the sections of the hollows and projecting parts being formed like a dove's tail, is called *dovetailing*.

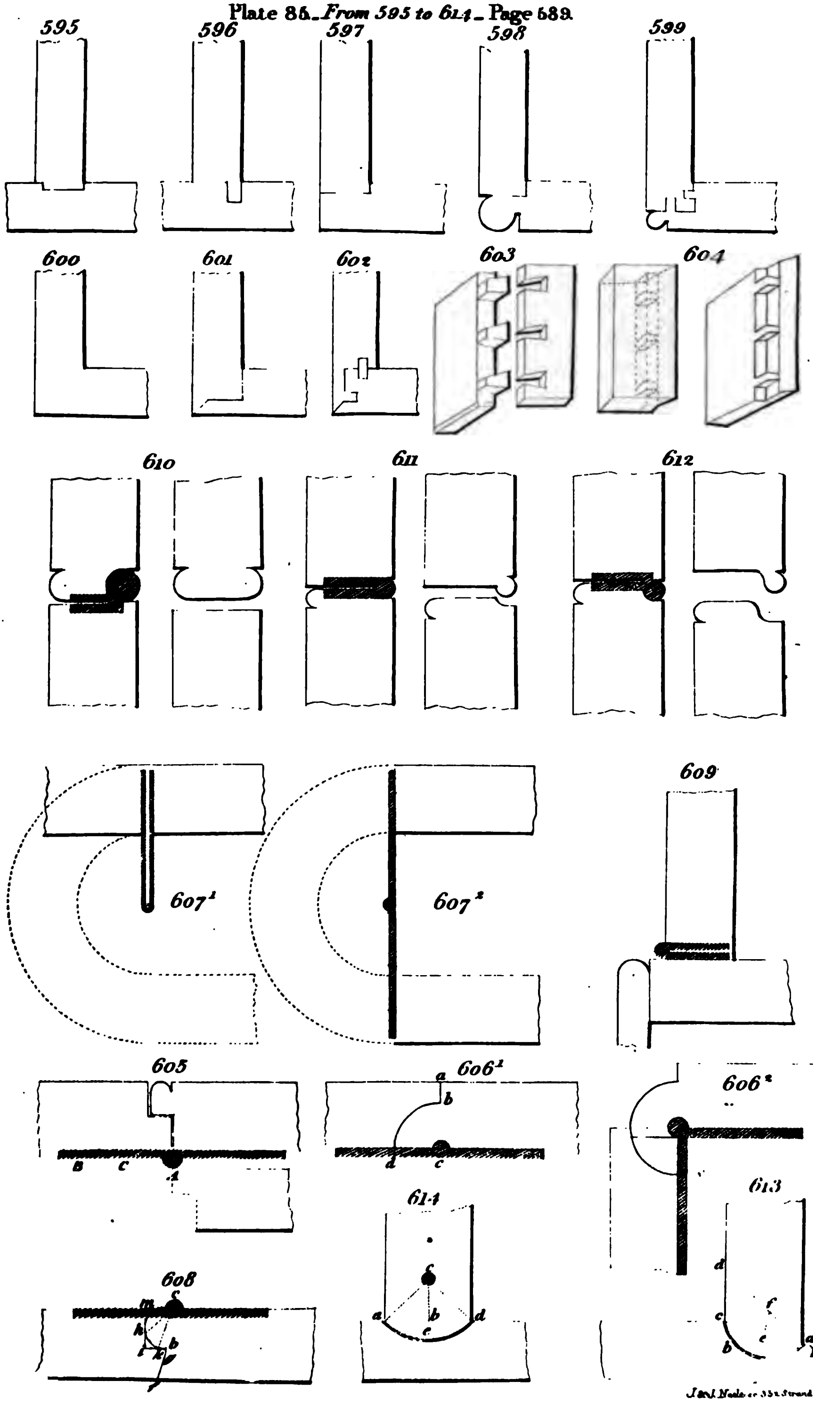
There are three sorts of *dovetailing*; viz. common, lap, and mitre. Common dovetailing shews the form of the projecting parts, as well as of the excavations made to receive them; lap dovetailing conceals the dovetail, but shews the thickness of the lap on the return side; and mitre dovetailing conceals the dovetail and shews only a mitre on the edges of the planes at the surface of the concourse; that is, the edges in the same plane, the seam or join being in the concourse of the two faces, making the given angle with each other.

Concealed dovetailing is particularly useful where the faces of the boards are intended to form a saliant angle; but when the faces form a re-entrant angle, common dovetailing is preferable.

There is another simple and expeditious manner of connecting the ends of boards together where the faces form a re-entrant, or internal angle, by means of a groove in the one, and a tongue in the other; and if the pieces be pre

BUILDING

Plate 85_From 595 to 614_Page 689.



J & J. Neale sc 352 Strand

viously nailed so that the nails be not seen in the faces, tnis will answer every purpose of common-dovetailing.

As various methods are employed in connecting pieces of wood so as to form an angle, we shall here present the reader with some of the best examples.

Figs. 595 and 596 are methods of connecting two pieces of wood so as to form two internal right angles.

Figs. 597, 598, 599, 600, 601, and 602, exhibit the joining of boards at an external angle.

In Figs. 598 and 599 the external angle, being that which is exposed to sight, is rounded or beaded.

Fig. 600 is the most common of mitres.

Fig. 601, a lapped mitre, which is much stronger than Fig. 600.

Fig. 602, a lapped and tongued mitre.

Fig. 603, dovetailing.

Fig. 604, secret dovetailing.

If several boards are required to be joined together to form a broad face, they are sometimes strengthened by fixing, with a tongue and groove, or mortise and tenon, another narrow piece across each end: the cross piece is termed a *clamp,* and the board thus constructed is said to be *clamped.*

The most simple description of door is constructed of several boards simply rebated together, or each edge ploughed and tongued; these are confined together by a transverse piece, called a *ledge* nailed a cross, from which the door derives the name of a *ledge-door.*

When strength, durability, and beauty are to be combined, a frame, joined by mortise and tenon, is constructed with one or more openings; and these openings are filled with pieces called *panels,* fitted into grooves, ploughed in the edges of the frame. The horizontal pieces of the framing are called, according to their situation, *top-rail, bottom-rail, lock-rail,* and *frieze-rail.* On the lock-rail the lock is either mortised in, or screwed on; and the frieze-rail is an intermediate rail between the top and middle rail. The extreme vertical pieces to which the rails are fixed are called *stiles*; and if there be any intermediate piece it is called a *mounting.*

Doors derive their names according to the manner in which they are framed and the number of panels they contain, as one, two, four, six, &c. panelled doors; and are further described by the moulding and description of panel.

Jib-doors are those which, when shut, are as much concealed as possible. They are used to preserve the uniformity of a room, or to save the expense of a corresponding

door. Doors ought to be made of the best materials, perfectly seasoned, and firmly put together; the mitres or scribings should be brought together with the greatest exactness, and the whole of their surfaces be perfectly smooth.

The mortising, tenoning, ploughing, and sticking of the mouldings, ought to be worked correctly to the gauge-lines; otherwise the door, when put together, will be out of truth, and occasion the workman a great deal of trouble, paring the different parts to make it appear satisfactory: the door will also lose much of its firmness, especially if the mortises and tenons require to be pared.

In bead and flush doors, make the work square, afterwards put in the panels, and smooth the whole off together; then, marking the panels at the parts of the framing to which they agree, take the door to pieces, and work the beads on the stiles, mountings, and rails. If the doors are double margin, that is, representing a pair of folding doors, the staff stile, which imitates the meeting-stiles, must be inserted into the top and bottom rails of the door, by forking the ends into notches cut in the top and bottom rails.

In the hanging of doors, the chief aim is to clear the carpet or ground; which may be accomplished by observing the following rules. First, let the floor be raised under the door, according to the intended thickness of the carpet; secondly, let the knuckles of the top and bottom hinges be so placed, that the top hinge hang, or project, about one eighth of an inch over the lower; that is, if the hinge be let equally into the door and into the jamb, project a little beyond the surface of the door; but if the centre lie in the surface of the door, it must be placed at the very top, which is seldom done, except when the door is hung with centres. Thirdly, let the jamb on which the door hangs, be fixed about an eighth of an inch out of the perpendicular, the upper part inclining towards the opposite jamb; and fourthly, let the inclination of the rebate be such, that the door shall, when shut, project at the bottom, towards the room, about an eighth of an inch.

These several methods, practised on so small a scale, are not perceptible; but, nevertheless, will throw the door, when opened, to a square sufficiently out of the level; that is, at least half an inch, when the height of the door is double the width.

Several kinds of rising hinges have been introduced for this purpose: some of the best, constructed of brass, are by no means objectionable, even to the best doors.

Before we proceed to the principles of *hanging* doors, we shall submit to the reader some information on the subject of *hinging* in general.

The placing of hinges depends entirely on the form of the joint, and as the motion of the door or closure is angular, and performed round a fixed line as an axis, the hinge must be so fixed that the motion be not interrupted : thus, if the joint contain the surface of two cylinders, the convex one in motion upon the edges of the closure, and sliding upon the concave one which is at rest on the fixed body, the motion of the closure must be performed on the axis of the cylinder, which axis must be the centre of the hinges. In this case, whether the aperture be shut or open, the joint will be close ; but if the joint be a plane surface, it is necessary to consider upon what side of the aperture the motion is to be performed, as the hinge must be placed on the side of the closure where it revolves.

The hinge is made in two parts, movable in any angular direction, the one upon the other.

The knuckle of the hinge is a portion contained under a cylindric surface, and is common both to the moving part and the part which is at rest; the cylinders are indented into each other, and are made hollow to receive a concentric cylindric pin, which passes through them, and connects the moving parts together.

The axis of the cylindrical pin, is called the *axis of the hinge.*

When two or more hinges are placed upon a closure, the axis of the hinges must be in the same straight line.

The straight line in which the axis of the hinges are placed is called the *line of hinges.*

We shall now proceed to the principle of hanging doors, shutters, or flaps, with hinges.

The centre of the hinge is generally put in the middle of the joint, as at A, Fig. 605, but in many cases there is a necessity for throwing back the flap to a certain distance from the joint ; in order to effect this, suppose the flap when folded back, were required to be at a certain distance from the joint, as BA, Fig. 605, divide BA in two equal parts at the point C, and it will give the centre of the hinge. The centre of the hinge must be placed a small degree beyond the surface of the closure, otherwise it will not fall freely back on the jamb, or partition. It must also be observed, that, the centre of the hinge must be on the same side as the rebate, or it will not open without the joint being constructed in a particular form.

To hang two flaps, so that when folded back, they shall be at a certain distance from each other.

This is easily accomplished by means of hinges having knees project-

ing to half that distance, as appears from Fig. 607: this sort of hinge is used in hanging the doors of pews, in order to clear the moulding of the coping. Fig. 607, No. 2, shows the same hinge opened.

To make a rule joint for a window-shutter, or other folding flap.

Fig. 606, No. 1. Let *a* be the place of the joint, draw *a c* at right angles to the flap, shutter, or door, take *c*, in the line *a c*, for the centre of the hinge, and the plain part *a b*, as may be thought necessary; or *c*, with a radius, *c b*, describe the arc *b d;* then will *a b d* be the true joint. The knuckle of the hinge is always placed in the wood; because the further it is inserted, the more of the joint will be covered when it is opened to a right angle, as in Fig. 606, No. 2; but if the centre of the hinge were placed the least without the thickness of the wood, it would show an open space, which would be a blemish.

To form the joints of stiles, to be hung together, when the knuckle of the hinge is placed on the contrary side of the rebate.

Fig. 608. Let *c* be the centre of the hinge, *m i* the joint on the same side, *c b* the depth of the rebate in the middle of the thickness of the styles, perpendicular to *i m*, and *l f* the joint on the other side, parallel to *i m;* bisect *i l* at *k*, join *k c*, on *k c* describe a semicircle *c i k*, cutting *i m* at *h*, through the points *h* and *k* draw *h k g*, cutting *f l* at *g;* then will *f g*, *h m*, be the true joint.

Fig. 609 represents the common method of hanging shutters together, the hinge being let the whole of its thickness into the shutter, and not into the sash-frame. By this mode it is not so firmly hung as when half of it is let into the shutter, and half into the sash-frame; but the lining may be made thinner.

It may here be proper to observe, that the centre of the hinge must be in the same plane with the face of the shutter, or beyond it, but not within the thickness.

How to construct a joint for hanging doors with centres.

Fig. 614. Let *a d* be the thickness of the door, bisect it in *b*, draw *b c* perpendicular to *a b*, make *b c* equal to *b a*, or *b d*, or *c*, the centre of the hinge, with a radius *c a*, or *c d*, describe an arc, *a e d*, which will give the joint required.

Another plan is represented in Fig. 613. Draw *a b* parallel to the jamb, meeting the other side in *b*, make *b d* equal to *b a*, and join *a d* and *a c*, bisect *a c* by a perpendicular *e f*, meeting *a d* in *f*, then *f* is the centre of the hinge.

Figs. 610, 611, and 612, exhibit different methods of hanging flaps, &c. These are so very simple, that by a little attention the reader will readily perceive their uses and manner of construction.

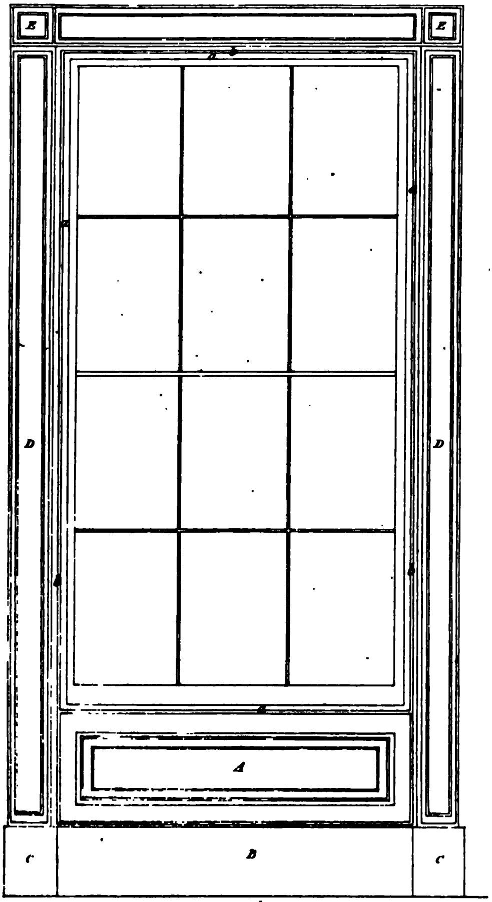
We shall now detail the construction of sash-frames, sashes, and shutters, and the manner of putting the several parts together.

Fig. 615, No. I, the elevation; No. 2, the plan; and No. 3, the section same; showing the manner in which the different parts are con-

BUILDING

Plate 86. — *From 615 to 617* — Page 592.

616²



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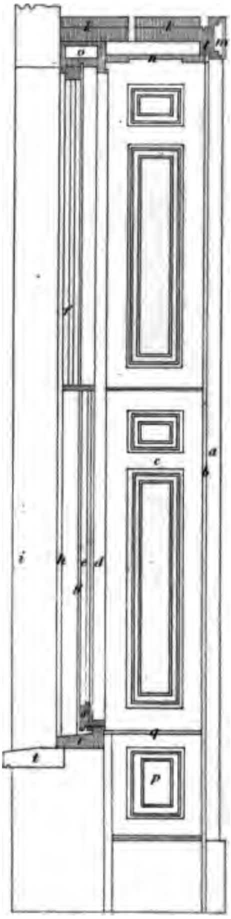

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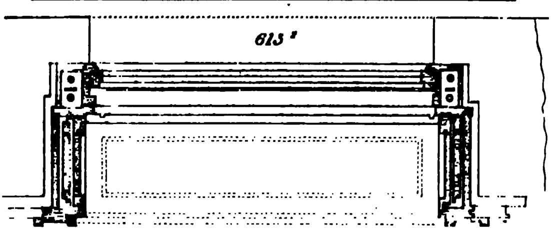

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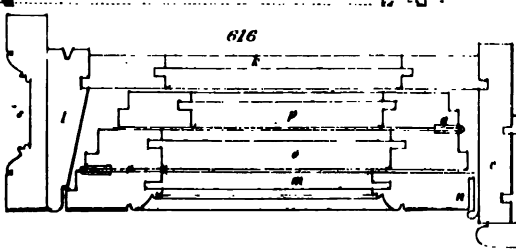
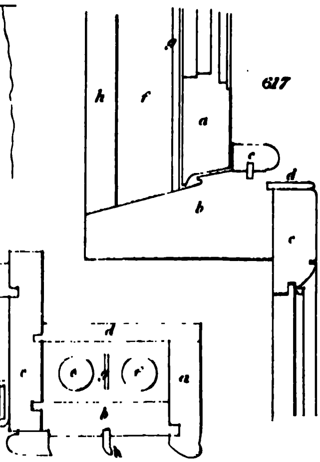


617



No. 1. A Back.—B Flush skirting, separated from the back by flush reeds, and showing the same depth of plinth as the blocks of the pilasters.—C C Blocks or plinths to pilasters.—D D Pilasters.—E E Patteras. —*a a a a* Inside bead of sash-frame.—*b b b* rounded edge of boxing-stile.

No. 2. Plan of sash-frame, shutters, pilasters, and the different parts are explained in the figures.

No. 3. *a* thickness of the pilaster or architrave; *b* the rounded edge of the boxing-stile; *c* the breadth of the shutter; *d* bead of the sash-frame; *e* under sash; *f* top ditto; *g* parting bead; *h* outside lining and bead. *i* the breadth of the reveal or outer brick-work; *k k* lintels made of strong yellow deal or oak; *l* the head of the ground; *m* the architrave or pilaster fixed upon the grounds; *n* the soffit, tongued into the top of the sash-frame-head; and, on the other edge, into the head of the architrave *m*; *o* the sash-frame head; *p* the elbow; *q* capping; *r* sash-frame cill; *s* sash-cill; *t* stone-cill.

The face of the pulley-stile of every sash-frame ought to project about three-eighths of an inch beyond the edge of the brick-work; that is, the distance between the face of each pulley-stile ought to be less by three quarters of an inch than in the clear of the reveals on the outside; so that the face of the shutters ought to be in the same plane with the stone or brick-work on the outside.

Fig. 616 shows a plan of a sash-frame and shutter on the same principle as the foregoing, and which may be applied to a similar window.

As the thickness of the wall is here conceived to be less than in the foregoing example, another back-flap is introduced:—*a* the outside lining; *b* the pulley-stile; *c* the inside lining; *d* the back lining; *e f* the weights; *g* parting slip of weights; *h* parting bead to sashes; *i* inside bead; *k* back lining of boxing; *l* ground, or boxing-stile, grooved to receive the plastering; *m* front shutter hung to the inside lining, *c*, of the sash-frame by the hinge *n*; *o p* back flaps hinged together at *q*, and to the shutter at *r*; *s* architrave or pilaster.

Fig. 617. Is a vertical section of the cill, &c. of the same sash-frame; *a* bottom rail of sash; *b* cill of the sash-frame; *c* back of recess of window; *d* coping bead, or capping let into the sash-frame cill; *e* inside bead, tongued on the top of the cill; *h* outside lining; *f* space for the top-sash to run in; *g* parting bead.

STAIRS.

This is one of the most important subjects connected with a joiner's art, and should be attentively considered, not only with regard to the situation, but as to the design and execution. The convenience of the building depends on the situation; and the elegance, on the design and execution of the workmanship. In contriving a grand edifice, particular attention must be paid to the situation of the space occupied by the stairs, so as to give them the most easy command of the rooms.

With regard to the lighting of a good staircase, a sky-light, or rather lantern, is the most appropriate; for these

unite elegance with utility, that is, admit a powerful light, with elegance in the design; indeed, where the staircase does not adjoin the exterior walls, this is the only light that can be admitted. Where the height of a story is considerable, resting places are necessary, which go under the name of *quarter-paces*, and *half-paces*, according as the passenger has to pass one or two right-angles; that is, as he has to describe a quadrant or semi-circle. In very high stories, which admit of sufficient head-room, and where the space allowed for the staircase is confined, the staircase may have two revolutions in the height of one story, which will lessen the height of the steps; but in grand staircases only one revolution can be admitted, the length and breadth of the space on the plan being always proportioned to the height of the building, so as to admit of fixed proportions.

The breadth of the steps ought never to be more than 15 inches, or less than nine; the height not more than seven, or less than five: there are cases, however, which are exceptions to all rule. When the height of the story is given in feet, and the height of the step in inches, you may throw the feet into inches, and divide it by the number of inches the step is high, and the quotient will give the number of steps.

It is a general maxim, that the greater breadth of a step requires less height than one of less breadth: thus, a step of 12 inches in breadth will require a rise of $5\frac{1}{2}$ inches, which may be taken as a standard, to regulate those of other dimensions.

Though it is desirable to have some criterion as a guide in the arrangement of a design, yet workmen will, of course, vary them as circumstances may require. Stairs are constructed variously, according to the situation and destination of the building.

Geometrical stairs are those which are supported by having one end fixed in the wall, and every step in the ascent having an auxiliary support from that immediately below it, and the lowest step from the floor.

Bracket-stairs are those which have an opening or well, with strings and newels, and are supported by landings and carriages; the brackets are mitred to the ends of each riser, and are fixed to the string-board, which is moulded below like an architrave.

Dog-legged stairs are those which have no opening, or well-hole, and have the rail and balusters of both the progressive and returning flights falling in the same vertical

planes, the steps being fixed to strings, newels, and carriages, and the ends of the steps of the inferior kind terminating only upon the side of the string, without any housing. In taking dimensions and laying down the plan and section of stair-cases, take a rod, and, having ascertained the number of steps, mark the height of the story, by standing the rod on the lower floor: divide the rod into as many equal parts as there are to be risers, then, if you have a level surface to work upon below the stair, try each of the risers as you go on, and this will prevent any excess or defect; for any error, however small, when multiplied, becomes of considerable magnitude, and even the difference of an inch in the last riser, will not only have a bad effect to the eye, but will be apt to confuse persons not thinking of any such irregularity. In order to try the steps properly by the story rod, if you have not a level surface to work from, the better way will be, to lay two rods on boards, and level their top surface to that of the floor: place one of these rods a little within the string, and the other near or close to the wall, so as to be at right angles to the starting line of the first riser, or, which is the same thing, parallel to the plan of the string; set off the breadth of the steps upon these rods, and number the risers; you may set not only the breadth of the flyers, but that of the winders also. In order to try the story-rod exactly to its vertical situation, mark the same distances of the risers upon the top edges, as the distances of the plan of string-board, and the rods are from each other.

In bracket-stairs, as the internal angle of the steps is open to the end, and not closed by the string as in common dog-legged stairs, and the neatness of workmanship is as much regarded as in geometrical stairs, the balusters must be neatly dove-tailed into the ends of the steps, two in every step. The face of each front baluster must be in a straight surface with the face of the riser, and, as all the balusters must be equally divided, the face of the middle baluster must stand in the middle of the face of the riser of the preceding step and succeeding one. The risers and heads are all previously blocked and glued together, and when put up, the under side of the step nailed or screwed into the under edge of the riser, and then rough brackets to the rough strings, as in dog-legged stairs, the pitching pieces and rough strings being similar. In glueing up the steps, the best method is to make a templet, so as to fit the external angle of the steps with the nosing.

The steps of geometrical stairs ought to be constructed so as to have a very light and clean appearance when put up: for this purpose, and to aid the principle of strength, the risers and treads, when planed up, ought not to be less than one eighth of an inch, supposing the going of the stair, or length of the step, to be four feet, and for every six inches in length, another one-eighth may be added. The risers ought to be dove-tailed into the cover, and when the steps are put up, the treads are screwed up from below to the under edge of the risers. The holes for sinking the heads of the screws ought to be bored with a centre-bit, then fitted closely in with wood, well matched, so as entirely to conceal the screws, and appear as one uniform surface. Brackets are mitred to the riser, and the nosings are continued round. In this mode, however, there is an apparent defect; for the brackets instead of giving support, are themselves unsupported, and dependent on the steps, being of no other use, in point of strength, than merely tying the risers and treads of the internal angles of the steps together: and, from the internal angles being hollow, or a re-entrant angle, except at the ends, which terminate by the wall at one extremity, and by the brackets at the other, there is a want of regular finish. The cavetto, or hollow, is carried round the front of the riser, and is returned at the end, and mitred round the bracket, and if an open string, that is, the under side of the stairs open to view, the hollow is continued along the angle of step and riser.

The best plan, however, of constructing geometrical stairs is, to put up the strings, and to mitre the brackets to the risers, as usual, and enclose the soffit with lath and plaster, which will form an inclined plane under each flight, and a winding surface under the winders. In superior staircases, for the best buildings, the soffit may be divided into panels. If the risers are made from two inch planks, it will greatly add to the solidity. The method of drawing and executing the scroll, and other wreath parts of the hand-rail, will be given in a subsequent part of this article.

In constructing a flight of geometrical stairs, where the soffit is inclosed as above, the bearers should all be framed together, so that when put up, they will form a perfect staircase. Each piece of frame-work, which forms a riser, should, in the partition, be well wedged at the ends. This plan is always advisable when strength and firmness are requisite, as the steps and risers are entirely dependent on the

framed carriages, which, if carefully put together, will never yield to the greatest weight.

Fig. 619 will show the section of this framing firmly put together, and wedged into the partition, as above described.

In preparing the string for the wreath part, a cylinder should be made of the size of the well-hole of the staircase, which can be done at a trifling expense; then set the last tread and riser of the flyers on one side, and the first tread and riser of the returning flight on the opposite side, at their respective heights; then on the centre of the curved surface of this cylinder, mark the middle between the two, and with a thin slip of wood, bent round with the ruling edge, cutting the two nosings of these flyers and passing through the intermediate height marked on the cylinder, draw a line, which will give the wreath line formed by the nosings of the winders; then draw the whole of the winders on this line, by dividing it into as many parts as you want risers, and each point of division is the nosing of such winder. Having thus far proceeded, and carefully examined your heights and widths, so that no error may have occurred, prepare a veneer of the width intended for your string, and the length given by the cylinder, and after laying it in its place on the cylinder, proceed to glue a number of blocks about an inch wide on the back of the veneer, with their fibres parallel to the axis of the cylinder. When dry, this will form the string for the wreath part of the staircase, to be framed into the straight strings. It is here necessary to observe, that about five or six inches of the straight string should be in the same piece as the circular, so that the joints fall about the middle of the first and last flyers. This precaution always avoids a cripple, to which the work would otherwise be subject.

Fig. 618, No. 1, is a plan of a dog-legged staircase, *a* the seats of the newels, *c* the seat of the upper newel.

No. 2. The elevation of the same.

AB. The newels; the part AC being turned.—DE the upper newel.—FG the carriage piece.—HI upper string board framed into the newel.—K a joist framed into the trimmer.

To describe the ramps; produce the horizontal part of the knee to L, and also the under side of the rail until it meets the face of the first baluster, at *c*, make *c d* equal to *c* D, and upon A *d*, and from the point *d*, draw the perpendicular *d* L, and L is the centre for describing the ramps *d* D.

The story-rod *a b* is a very necessary article in fixing the steps; for, if a common rule be used for this purpose, the workmen will be very liable to err and render the stairs extremely faulty, which cannot take place if the story-rod be applied to every riser, and the successive risers be regulated by it.

In the construction of dog-legged staircases, the first thing is, to take the dimensions of the stair, and the height of the story, and lay down a plan and section upon a floor to the full size, representing all the newels and steps; then the situation of the carriages, pitching pieces, long and cross bearers, as also the string boards; the strings, rails, and newels, being framed together, must be fixed with temporary supports. The string-board will show the situation of the pitching-pieces, which must be put up in order, wedging one end firmly into the wall, and fixing the other to the string-board; this being done, pitch up the rough strings, and finish the carriage part of the flyers. Having proceeded thus far, the steps are next applied, beginning at the bottom and working upwards, the risers being all firmly nailed into the treads.

In the best kind of dog-legged stairs, the nosings are returned; sometimes the risers are mitred to the brackets, and sometimes mitred with quaker strings. In the latter case a hollow is mitred round the internal angle of the under side of the tread, and the face of the riser. Sometimes the string is framed into the newel, and notched to receive the ends of the steps; the other end having a corresponding notch-board, and the whole flight being put up like a step-ladder.

Fig. 619, No. 1 and 2, is a plan and elevation of a geometrical staircase. The lower part, No. 2, shows the section of the steps and carriages, which are framed together as directed in a former part of this article.

The methods of finding the different moulds necessary in the formation of the wreath part of the hand-rail, will be found in the next plate.

To draw the scroll of a hand-rail.

Fig. 620. First make a circle 3½ inches in diameter, divide the diameter into three equal parts, make a square in the centre of the circle equal to one of those parts, and divide each side of the square into six equal parts.

Fig. 4, shows this square on a larger scale, and laid in the same position as the little square above, with the different centres marked. The centre at 1 draws from *a* to *b*, the centre at 2 from *b* to *c*, and the centre at 3 from *c* to *d*, &c. which will complete the outside revolution at A: set the thickness of the rail from *e f* and to *x*, draw the inside the reverse way, and the scroll will be completed.

To draw the curtail-steps.

Set the balusters in their proper places on each quarter of the scroll, Fig. 3, the first baluster showing the return of the nosing round the step, the second placed at the beginning of the twist, and the third a quarter distant, and straight with the front of the last riser; then set the projection of the nosing without, and draw it round equally distant from the scroll, which will give the form of the curtail.

As the method of getting a scroll out of a solid piece of wood, having the grain of the wood to run in the same direction with the rail, is far preferable to any other method with joints, being much stronger and more beautiful than any other scroll with one or two joints, we shall here give the method of finding a face-mould to apply on the face of the plank.

Place your pitch board *l m n* with *m n* passing through the eye of the scroll, then draw ordinates across the scroll at discretion, and take the length of the line *o n*, with its divisions, and lay it on *o n*, at Fig. 621, then the ordinate being drawn, take the different distances 2 *x*, 3 *z*, 4 *v*, &c. and transfer them to 2 *y*, 3 *z*, 4 *v*, &c. and the rest of the points being taken in the same manner, a curve may be traced which will be the face-mould required.

To find the parallel thickness of the plank.

Fig. 622. Let *l m n* be the pitch board, and let the level of the scroll rise one-sixth, that is, divide *l m* into six equal parts, and the bottom division is the top of the level of the scroll: from the end of the pitch board, set on *n* to *o*, half the thickness of a baluster, to the inside; then set, from *o* to *p*, half the width of the rail, and draw the form of the rail on the end at *p*, the point *n* being where the front of the riser comes, the point *p* will be the projection of the rail before it: draw a dotted line to touch the nose of the scroll, parallel with *l n*, then the distance between this dotted line and the under tip of the scroll, will show the exact thickness of planking; but there is no occasion for the thickness to come quite to the under side, for if it come to the under side of the hollow it will be sufficient, as a little bit glued under the hollow could not be discernible, and can be no hurt to the scroll. In ordinary cases, where the tread is about 11 inches, and rise 6½, a scroll can be got out of a piece, about 4½ inches thick.

To describe a section of a hand-rail, supposing it to be two inches deep, and two and a quarter inches broad, the usual dimensions.

Fig. 622. Let ABCD be a section of the rail, as squared; on AB describe an equilateral triangle AB *a*; from *a*, as a centre, describe an arc to touch AB, and to meet *a* A and *a* B; take the distance between the point of section in *a* A and the point A, and transfer it from the point of section to *k*, upon the same line *a* A, join D*k*; from *k*, with the distance between *k* and the end of the arc, describe another arc, to meet D*k*; with the same distance describe a third arc, of contrary curvature, and draw a vertical line to touch it; which will form one side of the section of the rail, and the counter part may be formed by a similar operation.

The branch of Joinery that falls under our next and last consideration is that of hand-railing; which calls into action all the ingenuity and skill of the workman. This art consists in constructing hand-rails by moulds, according to the geometrical principles, that if a cylinder be cut in any direction, except parallel to the axis, or base, the section will be an ellipsis; if cut parallel to the axis, a rectangle; and if parallel to the base, a circle.

Now, suppose a hollow cylinder be made to the size of the well-hole of the stair-case, the interior concave, and the exterior convex; and the cylinder be cut by any inclined or oblique plane, the section formed will be bounded by two concentric similar ellipses; consequently, the section will be at its greatest breadth at each extremity of the larger axis, and its least breadth at each extremity of the smaller axis. Therefore, in any quarter of the ellipsis there will be a continued increase of breadth from the extremity of the lesser axis to that of the greater. Now it is evident that a cylinder can be cut by a plane through any three points; therefore, supposing we have the height of the rail at any three points in the cylinder, and that we cut the cylinder through these points, the section will be a figure equal and similar to the face-mould of the rail; and if the cylinder be cut by another plane parallel to the section, at such a distance from it as to contain the thickness of the rail, this portion of the cylinder will represent a part of the rail with its vertical surfaces already worked: and, again, if the back and lower surface of this cylindric portion be squared to vertical lines, either on the convex or concave side, through two certain parallel lines drawn by a thin piece of wood which is bent on that side, the portion of the cylinder thus formed, will represent the part of the rail intended to be made.

Though the foregoing only relates to cylindrical well-holes, it is equally applicable to rails erected on any seat whatever.

The *face-mould* applies to the two faces of the plank, and is regulated by a line drawn on its edge, which line is vertical when the plank is elevated to its intended position. This is also called the *raking-mould.*

The *falling-mould,* is a parallel piece of thin wood applied and bent to the side of the rail-piece, for the purpose of drawing the back and lower surface, which should be so formed, that every level straight line, directed to the axis of the well-hole, from every point of the side of the rail formed by the edges of the falling mould, coincide with the surface.

In order to cut the portion of rail required, out of the least possible thickness of stuff, the plank is so turned up on one of its angles, that the upper surface is no where at right angles to a vertical plane passing through the chord of the plane; the plank in this position is said to be *sprung*

The *pitch-board,* is a right-angled triangular board made to the rise and tread of the step, one side forming the right

Join DE. Fig. 624, and produce DE to F. Draw DG and EL. Make DG equal to one-fourth (or any part of) the height from N to the upper edge of the falling mould, Fig. 625, and EL equal to one-fourth, or the same part, of the height from Q to the upper edge of the falling mould. Join GL and produce it to meet DE in F, join the dotted line BF. Draw IK, through the centre F, perpendicular to BF. Draw *a b*, *a b*, &c. meeting IK. At any convenient distance from KI draw *c d* parallel to IK. Make the perpendicular of the face-mould equal to its corresponding height on the falling mould, and draw the straight line *c e*; then draw ordinates A *b*, A *b*, &c. continue them until they meet *c e*, and from the points of intersection draw perpendiculars to *c e*, and set off the distances as shown by corresponding letters. Then by tracing a curve through these points the face mould will be completed.

The top line *r r r*, &c. is left on the falling mould, to regulate its position when bent upon the convex surface, as the line *r r r*, and will fall into the plane surface of the top of the plank. This line is obtained by making the perpendiculars *f r*, 2 *r*, *f r*, &c. equal to the corresponding perpendiculars *f b*, *f b*, &c. Fig. 624. To find the face-mould of a staircase, so that when set to its proper rake it will be perpendicular to the plan whereon it stands for a level landing.

Fig. 626. Draw the central line, *a b*, parallel to the sides of the rail, on the right line *a b* apply the pitch-board of a flyer, from *b* to *c* draw ordinates *n m*, *o p*, *q r*, *s t*, *u v*, at discretion, observing to draw one from the point *r*, so that you may obtain the same point exactly in the face-mould; then take the parts which the ordinates give on the line *a b*, and apply them at Fig. 627, and take the distances *m n*, *p o*, &c. and transfer them to Fig. 627, and a curve through these points will be the face-mould required.

To find the falling mould.

Fig. 626. Divide the radius of the circle into four equal parts, and set three of these parts from 4 to *a*; through *x y*, the extremities of the diameter of the rail, draw *a x* and *a y*, producing them till they touch the tangent AB; then will AB be the circumference of the semicircle *x b y*, which is applied from A to B, Fig. 628, as a base line. Make A *a* the height of a step; draw the hypotenuse *a* B, apply the pitch board of a flyer at *a b c*, and B *d e*, then curve off the angle by intersection of lines, and draw a line parallel to it, for the upper edge of the mould.

MEASURES CUSTOMARY IN JOINERS' WORK.

Prepared boarding is measured by the foot superficial; the following being the different distinctions:—edges shot; edge shot, ploughed, and tongued; wrought on one side, and edges shot; wrought on both sides, and edges shot; wrought on both sides, ploughed, and tongued; boards keyed and clamped, mortise-clamped, and mortise and mitre-clamped. The prices are regulated according to the thickness. If the boards be glued, an additional price per foot is allowed; if tongued, still more, according to the description of tongue. In boarded flooring, the dimensions are taken to the extreme parts, from which the squares are to be computed. Deductions for chimneys, stair-cases

&c. are taken from this. The price depends on the surface, whether wrought or plain, the manner of the longitudinal and heading-joints, the thickness of stuff, whether the boards be laid one after the other, or folded, or whether the floor be laid with boards, battens, or wainscot.

Skirting, when wide, is also measured by the foot superficial; the price depending upon the position, whether level, raking, or ramping, or upon the manner of finishing, whether plain, torus, or rebated, or scribed to the floor, or to the steps, or upon the plan, whether straight or circular.

Weather-boarding, is measured by the square of 100 superficial feet.

Boarded partitions are measured by the square, from which must be deducted the doors and windows, except an agreement be made to the contrary.

The price of all kinds of framing depends on the thickness, or whether the framing be plain or moulded; and if moulded, the description of moulding, whether struck on the solid, or laid in, mitred, or scribed; as also upon the number of panels in a given height and breadth, and upon the nature of the plan.

The different kinds of wainscotting, as window linings, door linings, back linings, partitions, doors, shutters, &c. are all measured by the superficial foot.

Windows are in general valued by the foot superficial; though sometimes by the window. When measured, the dimensions are taken for height, from the top of the cill to the under side of the head, allowing seven inches for the head and cill; and for width in clear of pulley-stiles, allowing eight inches. The sash and frame are either measured together or separately.

Skylights are measured by the foot superficial, their price depending on the plan and elevation. Framed grounds at per foot run.

Ledged doors by the foot superficial, dado by the superficial foot; the price depending whether the plan be straight or circular, or the elevation level or inclined.

In measuring stair-cases, the risers, treads, and carriages, are generally classed together, and measured by the foot superficial: the price varying as the steps are flyers or winders, as the risers are mitred into the string-board, the treads dove-tailed for balusters, and the nosings returned, or whether the bottom of the risers be tongued into the treads. The curtail step is generally valued as a whole. Returned nosings at so much each; and if circular, double the price of straight

ones. The brackets at so much each, according to the pattern, and whether straight or circular.

Hand-railing is measured by the foot run, the price depending on the materials, the diameter of the well-hole, or whether ramped, swan-necked, level, circular, or wreathed, or whether made out of the solid, or in thicknesses. The scroll is paid at per piece. The joints at so much each, and three inches of the straight part at each end of the wreath are included in the measurement. Deal balusters are prepared and fixed at per piece; as also iron balusters, iron column to curtail, housings to steps, &c. An extra allowance is made for the additional labour in fixing the iron balusters.

The price of string-board is regulated by the foot superficial, according to the manner in which it is moulded, whether straight, circular, or wreathed, and the manner in which such string is backed. The shafts of columns are measured by the foot superficial; the price depending upon the diameter, and whether it be straight or curved, or properly glued and blocked. If the column be fluted or reeded, the flutes or reeds are measured by the foot run, their price depending upon the size of the flute or reed. The headings of flutes and reeds are at so much each. Pilasters, straight or curved, in the height, are measured in the same way, and the price taken per foot superficial in the caps and bases if pilasters; besides the mouldings, the mitres must be so much each, according to the size.

Mouldings are valued by the foot run, as double-faced architraves, base and surbase. The head of an architrave in a circular wall, is four times the price of the perpendicular parts, not only on account of the time required to form the mouldings to the circular plan, but on account of the greater difficulty of forming the mitres.

All horizontal mouldings, circular upon plan, are three or four times the price of those on a straight plan; being charged more, as the radius of the circle is less: housings to mouldings are valued at so much each, according to the size.

The price per superficial foot of mouldings is regulated by the number of quirks, for each of which an addition is made to the foot.

The price of mouldings depends also upon the materials of which they are made, and upon their running figure, whether curved or raking.

In grooving, the stops are paid over and above, and so much more must be allowed for all grooves wrought by hand, particularly in the parts adjoining the concourse of

an angle: circular grooving must be paid still more. Water trunks are measured by the foot run; the rate depending upon the side of their square: the hopper-heads and shoes are valued at so much each, as also are the moulded weather caps, and the joints. Scaffolding, &c. used in fixing, is charged extra.

Flooring-boards are prepared, that is, planed, gauged, and rebated to a thickness at so much each, the price depending upon the length of each board; if more than nine inches broad, the rate is increased according to the additional width; each board listing at so much per list.

The following is a classification of such articles in joinery as are usually rated at so much each.

Trusses.
Cantalivers.
Rule-joints.
Cut brackets for shelves.
Housings in general.
Housings to steps.
Cuttings to standards.
Elbow cappings.
Returned moulded nosings to steps.
Caps to hand-rails.
Scroll of hand-rails.
Making and fixing joists of hand-rails with joint-screws.
Fixing iron columns in curtails.
Fixing iron baluster, and preparing mould.
Preparing and fixing deal balusters.
Brackets to stairs.
Curtail step.
Clamp-mitres.
Mitres of pilasters according to their size.
Mitres of cornices.
Headings to flutes and reeds.
Hopper-heads and shoes to water-trunks.
Joints to water-trunks.
Preparing flooring-boards and battens.
Fixing locks and fastenings, per article.
Hole in seat of water-closet.
Patteras.

Articles at per foot running, or lineal.

Sinking to shelves.
Moulded raisings of panels.
All raised panels in the extremity of the raising to be charged extra.
Capping to wainscot.
Level circular string-boards to stairs.
Hand-rails.
Newels to stairs.
Moulded planiers in stairs.
Sinking in rail for iron rail or balusters.
Water-trunks and spouts.
Skirting and door-grounds.
Beads or fillets.
Fillets mitred on panels,
Square or beaded angle-staff, rebated.
Mouldings.
Single cornice.
Single faced architrave.
Pilasters under four inches wide.
Boxings to windows.
Ornamental grooving.
Narrow linings.
Legs, rails, and runners of dressers.
Border to hearth.
Base-moulding.
Surbase-moulding.
Narrow skirting.

Articles at per foot superficial.

Deals planed, ploughed, tongued, beaded, glued, and clamped.
Skirting.
Sash-frames and sashes.

Skylights.
Back, elbow, soffits.
Shutters.
Framed or plain back-linings.
Door-linings, jambs.
Wainscotting.
Dado.
Partitions.
Steps and rises to stairs, including carriages,
Cradling.
Double-faced architraves.
Mouldings wrought by hand, if large.
Shafts of columns.

PLASTERING.

The Plasterer is a workman to whom the decorative part of architecture owes a considerable portion of its effect, and whose art is requisite in every kind of building.

The tools of the plasterer consist of a *spade* or shovel of the usual description; a *rake*, with two or three prongs, bent downwards from the line of the handle, for mixing the hair and mortar together; *trowels* of various kinds and sizes; stopping and picking-out tools; rules called *straight-edges;* and wood *models.*

The trowels used by plasterers are more neatly made than tools of the same name used by other artificers. The *laying and smoothing tool* consists of a flat piece of hardened iron, about ten inches in length, and two inches and a half wide, very thin, and ground to a semicircular shape at one end, but left square at the other; and at the back of the plate, near the square end, is rivetted a small iron rod with two legs, one of which is fixed to the plate, and the other to a round wooden handle. With this tool all the first coats of plaster is laid on, as are also the last, or, as it is technically termed, the *setting*. The other kinds of trowels are made of three or four sizes, for *gauging* the fine stuff and plaster, used in forming cornices, mouldings, &c. The longest size of these is about seven inches on the plate, which is of polished steel, about two inches and three quarters broad at the heel, diverging gradually to a point. To the heel or broad end a handle is adapted.

The *stopping and picking-out tools* are made of polished steel, of different sizes, though most generally about seven or eight inches in length, and half an inch in breadth, flattened at both ends, and ground somewhat round. These tools are used in modelling and finishing mitres and returns to cornices; as likewise in filling-up and perfecting the ornaments at the joinings.

The *straight-edges* are for keeping the work in an even, or perpendicular line; and the *models* or *moulds* are for run-

ning plain mouldings, cornices, &c.; of these latter the plasterer requires a great number as very little of his finishing can be done without them.

Experienced workmen keep their tools very clean, and have them daily polished by the hawk-boys.

Plasterers have technical divisions of their work, by which its quality is designated, and value ascertained; as, lathing; laying; pricking-up; lathing, laying, and set; lathing, floating, and set; screed, set or putty; rendering and set, or rendering, floated, and set; trowelled stucco, &c.; each of which, hereafter, we shall very minutely explain.

In all the operations of plastering, lime extensively abounds; we shall, therefore, first offer some observations on the properties of this important article.

All who have written on the subject of lime, as a cement, have endeavoured to ascertain what is the due proportion of sand for making the most perfect cement; but with a little attention it is evident, that all prescribed rules must be so very vague and uncertain, as to be of little utility to the workman, for, besides the variation which is occasioned by a more or less degree of calcination, it is a certain fact, that some kinds of lime-stone are much more pure, and contain a much smaller proportion of sand than others; consequently, it would be absurd to say, that pure lime requires as small a proportion of sand, when made into mortar, as that which originally contained in itself a large proportion.

The variation thus produced, in regard to the proportion of sand, is found to be extremely great. It is, however, stated, that the best mortar which has come under examination, was formed of eleven parts of sand to one of lime: to which was added, by measure, between twice and thrice its own bulk of sand, which may be allowed to have been at least three times its quantity by weight. Supposing, therefore, that every particle of the lime had been so perfectly calcined as to be in a caustic state, there could not be less than forty-seven parts of sand to one of lime; but it is hard to suppose, that above one hundredth part of this mass, independent of the water, consisted of pure caustic calcareous earth.

From these considerations it is conceived, that it is impossible to prescribe any determinate proportion of sand to lime, as that must vary according to the nature of the lime, and other incidental circumstances, which would form an infinity of exceptions to any general rule. But it would

seem, that it might be safely inferred, that the moderns in general rather err in giving too little, than in giving too much sand. It deserves, however, to be noticed, that the sand, when naturally in the lime-stone, is more intimately blended with the lime, than can possibly be ever effected by any mechanical operation; so that it would be in vain to hope to make equally good mortar artificially from pure lime, with so small a proportion of caustic calcareous matter, as may sometimes be effected when the lime naturally contains a very large proportion of sand. Still, however, there seems to be no doubt, that if a much larger proportion of sand than is common were employed, and that more carefully and expeditiously blended and worked, the mortar would be made much more perfect, as has been proved by actual experiments.

Another circumstance, which greatly tends to vary the quality of cement, and to make a greater or smaller proportion of sand necessary, is, the mode of preparing the lime before it is beaten up into mortar. When for plaster, it is of great importance to have every particle of the lime-stone slaked before worked-up, for, as smoothness of surface is the most material point, if any particles of lime be beaten-up before sufficiently slaked, the water still continuing to act on them, will cause them to expand, which will produce those excrescences on the surface of the plaster, termed blisters. Consequently, in order to obtain a perfect kind of plaster, it is absolutely necessary that the lime, before being worked, be allowed to remain a considerable time macerating or *souring* in water: the same sort of process, though not absolutely required, would considerably improve the lime intended for mortar. Great care is required in the management; the principal thing being the procuring of well-burnt lime, and allowing no more lime, before worked, than is just sufficient to macerate or *sour* it with the water: the best burnt lime will require the maceration of some days.

It has been almost universally admitted, that the hardest lime-stone affords the lime which will consolidate into the firmest cement; hence, it is generally concluded, that lime made of chalk produces a much weaker cement than that made of marble, or lime-stone. It would seem, however, that, if ever this be the case, it is only incidentally, and not necessarily. In the making of mortar, other substances are occasionally mixed with lime, which we shall here proceed to notice, and endeavour to point out their excellencies and

defects. Those commonly used, besides sand of various denominations, are powdered sand-stone, brick-dust, and sea-shells: and for forming plaster, where closeness rather than hardness is required, lime which has been slaked and kept in a dry place till it has become nearly effete, and powdered chalk, or whiting, and gypsum, in various proportions, besides hair and other materials of a similar nature. Other ingredients have been more lately recommended, such as earthy balls, slightly burnt and pounded, old mortar rubbish, powdered and sifted, and various things of the like kind, the whole of which are, in some respect or other, objectionable.

Plaster of Paris is employed by the plasterer to give the requisite form and finish to all the superior parts of his work.

It is made of a fossile stone, called gypsum, which is excavated in several parts of the neighbourhood of Paris, whence it derives its name, and is calcined to a powder, to deprive it of its water of crystallization. The best is Montmartre.

The stones are burnt in kilns, which are generally of very simple construction, being not unfrequently built of the gypsum itself. The pieces to be calcined are loosely put together in a parallelopiped heap, below which are vaulted pipes or flues, for the application of a moderate heat.

The calcination must not be carried to excess; as otherwise the plaster will not form a solid mass when mixed with a certain portion of water. During the process of calcination, the water of crystallization rises as white vapour, which, if the atmosphere be dry, is quickly dissolved in air.

The pounding of the calcined fragments is performed sometimes in mills constructed for the purpose, and sometimes by men, whose health is much impaired by the particles of dust settling upon their lungs.

On the river Wolga, in Russia, where the burning of gypsum constitutes one of the chief occupations of the peasantry, all kinds of gypsum are burnt promiscuously on grates made of wood; afterwards the plaster is reduced to powder, passed through a sieve, and finally formed into small round cakes, which are sold at so much per thousand.

These balls are reduced into an impalpable powder by the plasterer, and then mixed with mortar. The less the gypsum is mixed with other substances, the better it is qualified for the purpose of making casts, stucco, &c. The sparry gypsum, or selenite, which is the purer kind, is employed for taking impressions from coins and medals, and

for making those beautiful imitations of marble, granite, and porphyry, known by the name of *scagliola*, which is derived from the Italian word, *scagli*.

Finely powdered alabaster, or plaster of Paris, when heated in a crucible, assumes the appearance of a fluid, by rolling in waves, yielding to the touch, steaming, &c. all of which properties it again loses on the departure of the heat: if taken from the crucible and thrown upon paper, it will not wet it; but immediately be as motionless as it was before exposed to the heat.

Two or three spoonfuls of burnt alabaster mixed up thin with water, will, at the bottom of a vessel filled with water, coagulate into a hard lump, notwithstanding the water that surrounds it. The coagulating or setting property of burnt alabaster will be very much impaired, or lost, if the powder be kept for any considerable time, and more especially in the open air. When it has been once tempered with water, and suffered to grow hard, it cannot be rendered of any further use.

Plaster of Paris, diluted with water into the consistence of a soft or thin paste, quickly sets, or grows firm, and at the instant of its setting, has its bulk increased. This expansive property, in passing from a soft to a firm state, is one of its valuable properties; rendering it an excellent matter for filling cavities in sundry works, where other earthy mixtures would shrink and leave vacuities, or entirely separate from the adjoining parts. It is also probable that this expansion of the plaster might be made to contribute to the elegance of the impressions it receives from medals, &c. by properly confining it when soft, so that, at its expansion, it would be forced into the minutest traces of the figures.

A plaster of a coarser description, made of a blueish stone, much like that of which Dutch terras are made, is sometimes used in this country, for floors in gentlemen's houses, and for corn-granaries. This stone, when burnt after the manner of lime, assumes a white appearance, but does not ferment on being mixed with water: when cold, it is reduced to a fine powder. About a bushel of this powder is put into a tub, and water is applied till it becomes liquid. In this state it is well stirred with a stick, and used immediately; for in less than a quarter of an hour it becomes hard and useless, as it will not allow of being mixed a second time.

Other cements are used by plasterers for inside work. The first is called *lime and hair*, or *coarse stuff*, and is pre-

pared as common mortar, with the addition of hair from the tan-yards. The mortar is first mixed with a requisite quantity of sand, and the hair is afterwards worked in by the application of a rake.

Next to this is *fine stuff*, which is merely pure lime, slaked first with a small quantity of water, and afterwards, without any extraneous addition, supersaturated with water, and put into a tub in a half fluid state, where it is allowed to remain till the water is evaporated. In some particular cases, a small portion of hair is incorporated. When this fine stuff is used for inside walls, it is mixed with very fine washed sand, in the proportion of one part sand to three parts of fine stuff, and is then called *trowelled* or *bastard stucco*, with which all walls intended to be painted are finished.

The cement called *gauge stuff*, consists of three-fifths of fine stuff, and one-fifth plaster of Paris, mixed together with water, in small quantities at a time, to render it more ready to set. This composition is mostly used in forming cornices and mouldings run with a wooden mould. When great expedition is required, plasterers gauge all their mortars with plaster of Paris, which sets immediately.

The technical divisions of plasterer's work shall now claim our attention.

Lathing, the first operation, consists in nailing laths on the ceiling, or partition. If the laths be of oak, they will require wrought iron nails; but if of deal, nails made of cast iron may be used. Those mostly used in London are of fir, imported from America and the Baltic, in pieces called staves. Laths are made in three foot and four foot lengths: and with respect to their thickness and strength, are either single, lath and half, or double. The single are the thinnest and cheapest; those called *lath and half*, are supposed to be one third thicker than the single; and the double laths are twice that thickness. In lathing ceilings, the plasterer should use both the lengths alluded to, and in nailing them up, should so dispose them, that the joints be as much broken as possible, that they may have the stronger key or tie, and thereby strengthen the plastering with which they are to be covered. The thinnest laths are used in partitions, and the strongest for ceilings.

Laths are also distinguished into heart and sap laths: the former should always be used in plain tiling; the latter, which are of inferior quality, are most frequently used by the plasterer.

Laths should be as evenly split as possible. Those that are very crooked should not be used, or the crooked part should be cut out; and such as have a short concavity on the one side, and a convexity on the other, not very prominent, should be placed with the concave sides outwards.

The following is the method of rending or splitting laths. The lath-cleavers having cut their timber into the required lengths, cleave each piece with wedges, into eight, twelve, or sixteen pieces, according to the scantling of the timber, called *bolts;* and then, with dowl-axes, in the direction of the felt-grain, termed *felting*, into sizes for the breadth of the laths; and, lastly, with the *chit*, clear them into thicknesses by the *quarter grain.*

Having nailed the laths in their appropriate order, the plasterer's next business is to cover them with plaster, the most simple and common operation of which, is *laying;* that is, spreading a single coat of lime and hair over the whole ceiling, or partition; carefully observing to keep it smooth and even in every direction. This is the cheapest kind of plastering.

Pricking up is performed in the same manner as the foregoing; but is only a preliminary to a more perfect kind of work. After the plaster is laid on, it is crossed all over with the end of a lath, to give it a tie or key to the coat which is afterwards to be laid upon it.

Lathing, laying, and set, or what is termed *lath and plaster, one coat and set,* is, when the work, after being lathed, is covered with one coat of lime and hair, and afterwards, when sufficiently dry, a thin and smooth coat spread over it, consisting of lime only, or, as the workmen call it, *putty*, or *set.* This coat is spread with a smoothing-trowel, used by the workman with his right hand, while his left hand moves a large flat brush of hog's bristles, dipped in water, backwards and forwards over it, and thus produces a surface tolerably even for cheap work.

Lathing, floating, and set, or *lath and plaster, one coat, floated and set,* differs from the foregoing, in having the first coat pricked up to receive the set, which is here called the *floating.* In doing this, the plasterer is provided with a substantial straight edge, frequently from ten to twelve feet in length, which must be used by two workmen. All the parts to be floated are tried by a plumb-line, to ascertain whether they be perfectly flat and level, and whenever any deficiency appears, the hollow is filled up with a trowel full or more of lime and hair only, which is termed *filling out,*

and when these preliminaries are settled, the *screeds* are next formed. The term *screed* signifies a style of lime and hair, about seven or eight inches in width, gauged quite true, by drawing the straight edge over it until it be so. These screeds are made at the distance of about three or four feet from each other, in a vertical direction, all round the partitions and walls of a room. When all are formed, the intervals are filled up with lime and hair, called by the workmen, *stuff*, till flush with the face of the screeds. The straight edge is then worked horizontally on the screeds, by which all the superfluous stuff, projecting beyond them in the intervals is removed, and a plain surface produced. This operation is termed *floating*, and may be applied to ceilings as well as to partitions, or upright walls, by first forming the screeds in the direction of the breadth of the apartment, and filling up the intervals as above described. As great care is requisite to render the plaster sound and even, none but skilful workmen should be employed.

The *set* to floated-work is performed in a mode similar to that already prescribed for *laying;* but being employed only for best rooms, is done with more care. About one-sixth of plaster of Paris is added to it, to make it set more expeditiously, to give it a closer and more compact appearance, and to render it more firm and better calculated to receive the white-wash or colour when dry. For floated stucco-work the pricking up coat cannot be too dry; but, if the floating which is to receive the setting coat be too dry, before the set is laid on, there will be danger of its peeling off, or of assuming the appearance of little cracks, or shells. which would disfigure the work. Particular care and attention therefore must be paid to have the under coats in a proper state of dryness. It may here be observed, that cracks, and other unpleasant appearances in ceilings, are more frequently the effect of weak laths being covered with too much plaster, or too little plaster upon strong laths, rather than of any sagging or other inadequacy in the timbers, or the building. If the laths be properly attended to, and the plaster laid on by a careful and judicious workman, no cracks or other blemishes are likely to appear.

The next operation combines both the foregoing processes, but requires no lathing; it is called *rendering and set,* or *rendering, floated, and set.* What is understood by *rendering*, is the covering of a brick or stone wall with a coat of lime and hair, and by *set* is denoted a superficial coat of fine stuff or putty upon the rendering. These ope

rations are similar to those described for setting of ceilings and partitions; and the *floated and set* is laid on the rendering in the same manner as on the partitions, &c. already explained, for the best kind of work.

Trowelled stucco, which is a very neat kind of work, used in dining-rooms, halls, &c. where the walls are prepared to be painted, must be worked upon a floated ground, and the floating be quite dry before the stucco is applied. In this process the plasterer is provided with a wooden tool, called *a float*, consisting of a piece of half inch deal, about nine inches long and three wide, planed smooth, with its lower edges a little rounded off, and having a handle on the upper surface. The stucco is prepared as above described, and afterwards well beaten and tempered with clear water. The ground intended to be stuccoed is first prepared with the large trowel, and is made as smooth and level as possible; when the stucco has been spread upon it to the extent of four or five feet square, the workman, with a float in his right hand and a brush in his left, sprinkles with water, and rubs alternately the face of the stucco, till the whole is reduced to a fine even surface. He then prepares another square of the ground, and proceeds as before, till the whole is completed. The water has the effect of hardening the face of the stucco. When the floating is well performed, it will feel as smooth as glass.

Rough casting, or rough walling, is an exterior finishing, much cheaper than stucco, and, therefore, more frequently employed on cottages, farm-houses, &c. than on buildings of a higher class. The wall intended to be rough-cast, is first pricked-up with a coat of lime and hair; and when this is tolerably dry, a second coat is laid on, of the same materials as the first, as smooth as it can possibly be spread. As fast as the workman finishes this surface, he is followed by another with a pail-full of rough-cast, with which he bespatters the new plastering, and the whole dries together. The rough-cast is composed of fine gravel, washed from all earthy particles, and mixed with pure lime and water till the whole is of a semi-fluid consistency. This is thrown from the pail upon the wall with a wooden float, about five or six inches long, and as many wide, made of half-inch deal, and fitted with a round deal handle. While, with this tool, the plasterer throws on the rough-cast with his right hand, he holds in his left a common whitewashers' brush, dipped in the rough-cast also, with which he brushes and colours the mortar and the rough-cast he has already spread,

to give them, when finished, a regular uniform colour and appearance.

Cornices, are either plain or ornamented, and sometimes embrace a portion of both classes. The first point to be attended to is, to examine the drawings, and measure the projections of the principal members, which, if projecting more than seven or eight inches, must be bracketted. This consists in fixing up pieces of wood, at the distance of about ten or twelve inches from each other, all round the place proposed for the cornice, and nailing laths to them, covering the whole with a coat of plaster. In the brackets, the stuff necessary to form the cornices must be allowed, which in general is about one inch and a quarter. A beech mould is next made by the carpenter, of the profile of the intended cornice, about a quarter of an inch in thickness, with the quirks, or small sinkings, of brass or copper. All the sharp edges are carefully removed by the plasterer, who opens with his knife all the points which he finds incompetent to receive the plaster freely.

These preliminaries being adjusted, two workmen, provided with a tub of putty and a quantity of plaster of Paris, proceed to run the cornice. Before using the mould, they gauge a screed of putty and plaster upon the wall and ceiling, covering so much of each as will correspond with the top and bottom of the intended cornice. On this screed one or two slight deal straight-edges, adapted to as many notches or chases made in the mould for it to work upon, are nailed. The putty is then mixed with about one-third of plaster of Paris, and brought to a semi-fluid state by the addition of clean water. One of the workmen, with two or three trowels-full of this composition upon his *hawk*, which he holds in his left hand, begins to plaster over the surface intended for the cornice, with his trowel, while his partner applies the mould to ascertain when more or less is wanted. When a sufficient quantity of plaster is laid on, the workmen holds his mould firmly against both the ceiling and the wall, and moves it backwards and forwards, which removes the superfluous stuff, and leaves an exact impression of the mould upon the plaster. This is not effected at once; for while he works the mould backwards and forwards, the other workman takes notice of any deficiences, and fills them up by adding fresh supplies of plaster. In this manner a cornice from ten to twelve feet in length may be formed in a very short time; indeed, expedition is essentially requisite, as the plaster of Paris occasions a very great tendency in the putty

to set, to prevent which, it is necessary to sprinkle the composition frequently with water, as plasterers, in order to secure the truth and correctness of the cornice, generally endeavour to finish all the lengths, or pieces, between any two breaks or projections, at one time. In cornices which have very large proportions, and in cases where any of the orders of architecture are to be introduced, three or four moulds are required, and are similarly applied, till all the parts are formed. Internal and external mitres, and small returns, or breaks, are afterwards modelled and filled up by hand.

Cornices to be enriched with ornaments, have certain indentations, or sinkings, left in the mould in which the casts are laid. These ornaments were formerly made by hand; but now are cast in plaster of Paris, from clay models. When the clay model is finished, and has, by exposure to the action of the atmosphere, acquired some degree of firmness, it is let into a wooden frame, and when it has been retouched and finished, the frame is filled with melted wax, which, when cold, is, by turning the frame upside down, allowed to fall off, being an exact cameo, or counterpart, of the model. By these means, the most enriched and curiously wrought mouldings may be cast by the common plasterer. These wax models are contrived to cast about a foot in length of the ornament at once; such lengths being most easily got out from the cameo. The casts are made of the finest and purest plaster of Paris, saturated with water; and the wax mould is oiled previously to its being put in. When the casts, or intaglios, are first taken from the mould, they are not very firm; but being suffered to dry a little, either in the open air or an oven, they acquire sufficient hardness to allow of being scraped and cleaned.

Basso-relievos and friezes are executed in a similar manner, only the wax mould is so made, that the cast can have a back-ground at least half an inch thick of plaster-cast to the ornament or figure, in order to strengthen and secure the proportions, at the same time that it promotes the general effect.

The process for capitals to columns is also the same, except that numerous moulds are required to complete them. In the Corinthian capital a shaft or belt is first made, on which is afterwards fixed the foliage and volutes; the whole of which require distinct cameos.

In running cornices which are to be enriched, the plasterer takes care to have proper projections in the running-

mould, so as to make a groove in the cornice, for the reception of the cast ornament, which is laid in and secured by spreading a small quantity of liquid plaster of Paris on its back. Detached ornaments intended for ceilings or other parts, and where no running mould has been employed, are cast in pieces corresponding with the design, and fixed upon the ceiling, &c. with white-lead, or with the composition known by the name of *iron-cement*.

The manufacture of stucco has, for a long time past, attracted the attention of all connected with this branch of building, as well as chemists and other individuals; but the only benefit resulting from such investigation is, a more extensive knowledge of the materials used. It would seem, that the great moisture of our climate prevents its being brought to any high degree of perfection; though, among the various compositions which have been tried and proposed, some, comparatively speaking, are excellent.

Common stucco, used for external work, consists of clean washed Thames sand and ground Dorking lime, which are mixed dry, in the proportion of three of the latter to one of the former: when well incorporated together, these should be secured from the air in casks till required for use. Walls to be covered with this composition, must first be prepared, by raking the mortar from the joints, and picking the bricks or stones, till the whole is indented: the dust and other extraneous matter must then be brushed off, and the wall well saturated with clean water. The stucco is supersaturated with water, till it has the appearance and consistence of ordinary white-wash, in which state it is rubbed over the wall with a flat brush of hogs' bristles. When this process, called *roughing in*, has been performed, and the work has become tolerably dry and hard, which may be known by its being more white and transparent, the screeds are to be formed upon the wall with fresh stucco from the cask, tempered with water to a proper consistency, and spread on the upper-part of the wall, about eight or nine inches wide; as also against the two ends, beginning at the top and proceeding downwards to the bottom. In this operation, two workmen are required; one to supply the stucco, the other to apply the plumb-rule and straight-edge. When these are truly formed, other screeds must be made in a vertical direction, about four or five feet apart, unless apertures in the wall prevent it, in which case, they must be formed as near together as possible. When the screeding is finished, compo is prepared in larger quantities, and both the workmen spread

it with their trowels over the wall in the space left between each pair of screeds. When this operation is complete, the straight-edge is applied, and dragged from the top to the bottom of each pair, to remove whatever superfluous stucco may project above the screeds. If there be any hollow places, fresh stucco is applied, and the straight-edge is again drawn over the spot, till the compo is brought even to the face of the screeds, and the whole is level with the edge of the rule. Another interval is then filled up, and the workmen thus proceed till the whole of the wall is covered. The wall is finished by floating, that is, hardening the surface, by sprinkling it with water, and rubbing it with the common wood-float, which is performed similarly to trowelling stucco.

This description of compo is frequently used by plasterers for cornices and mouldings, in the same manner as described in common plastering; but if the workman finds it necessary, he may add a small quantity of plaster of Paris, to make it fix the better while running or working the mould. Such addition is not, however, calculated to give strength to the stucco, and is only made through the necessity of having a quick set.

In the year 1796, Mr. Parker obtained a patent for a cement that is impervious to water, and which may be successfully employed in ice-houses, cisterns, tanks, &c. In his specification Mr. Parker states, that "nodules of clay, or argillaceous stone, generally contain water in their centre, surrounded by calcareous crystals, having veins of calcareous matter. They are formed in clay, and are of a brown colour like the clay." These nodules he directs should, after being broken into small pieces and burnt in a kiln, with a heat that is nearly sufficient to vitrify them, be reduced to powder: when two measures of water added to five of this powder, will produce *tarras*. Lime and other matters may be added or withheld at pleasure; and the proportion of water may be varied.

The term of the patent being now expired, many other manufactories of this cement have been established, which produce it of equal goodness, and some of them of rather better colour, which is of importance, since the fresco-painting or white-wash, laid on Mr. Parker's composition, is soon taken off by the rain, and leaves the walls of a dingy and unpleasant appearance.

The fresco-painting, or staining, is laid on the walls covered with this cement, to give them the appearance of

stone buildings; and is performed by diluting sulphuric acid, (*oil of vitriol,*) with water, and adding fluid-ochres, &c. of the required tint.

When stucco is washed over with this mixture, the affinity existing in the iron of the cement ceases; and the acid and colour suspended in and upon the stucco are fixed. When dexterously managed, the surface assumes the appearance of an ashlar bond of masonry.

Scagliola is a distinct branch of plastering, discovered or invented, and much used in Italy, and thence introduced into France, where it obtained its name: the late Mr. H. Holland, who introduced it into England engaged artists from Paris, some of whom, finding a demand for their labour, remained in this country, and instructed the natives in the art.

Columns and pilasters are executed in this branch of plastering in the following manner: A wooden cradle, composed of thin strips of deal, or other wood, is made to represent the column designed; but about two inches and a half less in diameter than the shaft is intended to be when finished. This cradle is lathed round, as for common plastering, and then covered with a pricking up coat of lime and hair. When this is quite dry, the artists in scagliola commence operations, by imitations of the most rare and precious marbles, with astonishing and delusive effect; indeed, as the imitation takes as high a polish, and feels as cold and hard as the most compact and solid marble, nothing short of actual fracture can possibly discover the counterfeit.

In preparing the scagliola, the workman selects, breaks, and calcines the purest gypsum, and as soon as the largest fragments, in the process of calcination, lose their brilliancy, withdraws the fire, and passes the calcined powder through a very fine sieve, and mixes it, as required for use, with a solution of glue, isinglass, &c. In this solution the colours required in the marble to be imitated are diffused; but when the work is to be of various colours, each colour is prepared separately, and afterwards mingled and combined, nearly in the same manner as a painter mixes on his palette the primitive colours to compose his different tints.

When the powdered gypsum is prepared, it is laid on the, shaft of the intended column, over the pricked-up coat of lime and hair, and is then floated with moulds of wood, made to the requisite size: the artist uses the colours necessary for the imitation during the floating, by which means

they mingle and incorporate with the surface. To obtain the glossy lustre, so much admired in works of marble, the workman rubs the work with one hand with a pumice-stone, while with the other he cleans it with a wet sponge: he next polishes it with tripoli, charcoal, and a piece of fine linen; afterwards with a piece of felt dipped in a mixture of oil and tripoli, and finally completes the work by the application of pure oil. This imitation is, certainly, the most complete that can be conceived; and when the bases and capitals are made of real marble, as is the common practice, the deception is beyond discovery. If not exposed to the weather, it is, in point of durability, little inferior to real marble, retains its lustre full as long, and is not one-eighth of the expense of the cheapest kind.

There is another species of plastering, used in the decorative parts of architecture, and for the frames of pictures, looking-glasses, &c. which is a perfectly distinct branch of the art. This composition, which is very strong, and, when quite dry, of a brownish colour, consists of the proportion of two pounds of powdered whiting, one pound of glue in solution, and half a pound of linseed oil, mixed together, and heated in a copper, and stirred with a spatula, till the whole is incorporated. When cool, it is laid upon a stone, covered with powdered whiting, and beaten till it assumes a tough and firm consistence; after which it is covered with wet cloths, to keep it fresh, till required for use.

The ornaments to be cast in this composition, are modelled in clay, as in common plastering, and afterwards a cameo, or mould, is carved in box-wood. This carving requires to be done with the utmost care, otherwise the symmetry of the ornament which is to be cast from it will be spoiled. The composition, when required for use, is cut with a knife into pieces of the requisite size, and forced into the mould; after which it is put into a press, worked by an iron screw, and still further compressed. When the mould is taken from the press, the composition, which is generally cast about a foot in length, is dislodged from the mould, and the superfluous parts pared off with a knife, and cast into the copper for the next supply.

The ornaments thus formed, are glued upon wooden, or other grounds, or fixed by means of white lead, &c.; after which they are painted or gilt, according to the purposes for which they are intended. This composition is at least 80 per cent. cheaper than carving, and, in most cases, equally calculated to answer all the purposes of the art.

It is much to be wished, that the art of plastering could be restored to its ancient perfection; for the Romans possessed an art of rendering works of this kind much more firm and durable than can be accomplished at the present time.

The specimens of ancient Roman plastering still visible, which have not been injured by force, are found to be firm and solid, free from cracks or crevices, and as smooth and polished on the surface as when first applied. The sides and bottoms of the Roman aqueducts were lined with this plastering, and endured many ages.

At Venice, some of the roofs of houses, and the floors of rooms, are covered with a sort of plaster of later date, and yet strong enough to endure the sun and weather for several ages, without either cracking or spoiling.

The method of making the Venetian composition is not known in England; but such might probably be made by heating the powder of gypsum over a fire, and when boiling, which it will do without the aid of water, or other fluid, mixing it with resin, or pitch, or both together, with common sulphur, and the powder of sea-shells. If these be mixed together, water added to it, and the composition kept on the fire till the instant of its being used, it is not improbable that the secret may be discovered. Oil of turpentine and wax, which are the common ingredients in such cements as are accounted firmest, may also be tried as additions; as also may strong ale wort, which is by some directed to be used instead of water, to make mortar of lime-stone of more than ordinary strength.

SLATING

This branch of building, which is principally employed in the covering of roofs, is not unfrequently combined with that of plastering. The slates chiefly used in London are brought from the quarries at Bangor, in Caernarvonshire, which supply all parts of the United Kingdom. Another kind of slate, of a pale blue-green colour, is used, and most esteemed, being brought from Kendal, in Westmoreland, called *Westmoreland slates.* These slates are not large; but of good substance, and well calculated to give a neat appearance to a roof. The Scottish slate, which assimilates in size and quality to a slate from Wales, called *ladies,* is in little repute.

Slaters class the Welsh slates in the following order:

		Ft.	In.		Ft.	In.
Doubles,	average size,	1	1	by	0	6
Ladies,	————	1	3	—	0	8
Countesses,	————	1	8	—	0	10
Duchesses,	————	2	0	—	1	0
Welsh rags,	————	3	0	—	2	0
Queens,	————	3	0	—	2	0
Imperials,	————	2	6	—	2	0
Patent slate,	————	2	6	—	2	0

The *doubles*, are made from fragments of the larger kinds, and derive their name from their diminutive size. *Ladies* are similarly obtained. *Countesses* are a gradation above ladies; and *duchesses* above countesses.

Slate, like most other stony substances, is separated from its bed by the ignition of gunpowder. The blocks, thus obtained, are, by the application of wedges, reduced into layers, called *scantlings*, from four to nine inches in thickness, and of any required length and breadth, which are afterwards sawn to the respective sizes by machinery. The blue, green, and purple, or darker kinds of slate, are, in general, found capable of being split into very thin laminæ, or sheets; but those of the white or brownish free-stone kind, can seldom be separated or divided so fine; consequently, these last form heavy, strong, thick coverings, proper for buildings in exposed situations, such as barns, stables, and other out-houses.

The instruments used in splitting and cleaning slates are, slate-knives, axes, bars, and wedges; the three first being used to reduce the slates into the required thicknesses, and the last to remove the inequalities from the surface.

Imperial slating is particularly neat, and may be known by having its lower edge sawn; whereas all other slates used for covering are chipped square on their edges only.

Patent slate was first brought into use by Mr. Wyatt, the architect; but a patent was never obtained. It derives its name from the mode adopted to lay it on roofs; it may be laid on a rafter of much less elevation than any other, and is considerably lighter, by reason of the laps being less than is necessary for the common sort of slating. This slating was originally made from *Welsh rags;* but is now very frequently made from *Imperials,* which render it lighter, and also somewhat neater in appearance.

Westmoreland slate, from the experiments made by the late Bishop of Landaff, appears to differ little in its natural composition from that obtained from Wales. It must, however

be remarked, that this kind of slate owes its lightness, not so much to any diversity in the component parts of the stone, as to the thinness to which it is reduced by the workmen; consequently, it is not so well calculated to resist violent winds as those which are heavier.

Slates, when brought from the quarry, are not sufficiently square for the slater's use; he therefore picks up and examines the slates separately, and observes which is the strongest and squarest end; then, seating himself, he holds the slate a little slanting upon, and projecting about an inch over, the edge of a small block of wood, which is of the same height as his seat, and cuts away and makes straight one of its edges; then, with a slip of wood, he gauges, and cuts off the other edge parallel to it, and squares the end. The slate is now considered prepared for use, with the exception of perforating through its opposite ends two small holes, for the reception of the nails which are to confine it to the roof. Copper and zinc nails, or iron nails tinned, are considered the best, being less susceptible of oxidation than nails made of bar iron.

Before we proceed further with the operations necessary in the slating of building, we shall give some account of the tools used by this class of artificers.

Slaters' tools are very few, which sometimes are found by the masters, and sometimes by the men. The tool called the *saixe*, is made of tempered iron, about sixteen inches in length, and two inches in width, somewhat bent at one end, with a handle of wood at the other. This tool is not unlike a large knife, except that it has on its back a projecting piece of iron, about three inches in length, drawn to a sharp point. This tool is used to chip or cut all the slates to the required sizes.

The *ripper* is also of iron, about the same length as the saixe; it has a very thin blade, about an inch and three-quarters wide, tapered somewhat towards the top, where a round head projects over the blade about half an inch on each side: it has also two little round notches in the two internal angles at their intersections. The handle of this tool is raised above the blade by a shoulder, which enables the workman to hold it firm. This instrument is used in repairing old slating, and the application consists in thrusting the blade under the slates, so that the head, which projects, may catch the nail in the little notch at its intersection, and enable the workman to draw it out. During this

operation the slate is sufficiently loosened to allow of its being removed, and another inserted in its place.

The *hammer*, which is somewhat different in shape to the ordinary tool of that name, is about five inches in height on the hammer, or driving part, and the top is bent back, and ground to a tolerably sharp point, its lower or flat end, which is quite round, being about three-quarters of an inch in diameter. On this side of the driving part is a small projection, with a notch in the centre, which is used as a claw to extract such nails as do not drive satisfactorily.

The *shaving-tool* is used for getting the slates to a smooth face for skirtings, floors of balconies, &c. It consists of an iron blade, sharpened at one of its ends like a chisel, and mortised through the centre of two round wooden handles, one fixed at one end, and the other about the middle of the blade. The blade is about eleven inches long, and two inches wide, and the handle is about ten inches long, so that they project about four inches on each side of the blade. In using this tool, the workman places one hand on each side of the handle that is in the middle of the blade, and allows the other to press against both his wrists. In this manner he removes all the uneven parts from off the face of the slate, and gets it to a smooth surface.

The other tools used by the slater consist of chisels, gouges, and files of all sizes; by means of which he finishes the slates into mouldings and other required forms.

In slating roofs, it is necessary to form a base or floor for the slates to lay compactly and safely upon; for *doubles* and *ladies*, boarding is required, which must be laid very even, with the joints close, and properly secured by nails to the rafters. This being completed, the slater provides himself with several slips of wood, called *tilting fillets*, about ten inches and a half wide, and three-quarters of an inch thick on one edge, and chamfered to an arris on the other, which he nails down all round the extreme edges of the roof, beginning with the hips, if any, and if not, with the sides, eaves, and ridge. He next selects the largest of the slates, and arranges them regularly along the eaves with their lower edges to a line, and nails them to the boarding. This part of the work being completed, he takes other slates to form the bond to the under sides of the eaves, and places them under those previously laid, so as to cross and cover all their joints. Such slates are pushed up lightly under those which are above them, and are seldom nailed, but left dependent for support on the weight of those above

them, and their own weight on the boarding. The *countesses* and all other description of slates, when intended to be laid in a good manner, are also laid on boards.

When the slater has finished the eaves, he strains a line on the face of the upper slates, parallel to its outer edge, and as far from it as he deems sufficient for the lap of those he intends shall form the next course, which is laid and nailed even with the line, crossing the joints of the upper slates of the eaves. This lining and laying is continued close to the ridge of the roof, observing throughout to cross the different joints, by laying the slates one above another. The same system is uniformly followed in laying all the different sorts of slates, with the exception of those called *patent slates*, as are hereafter explained.

The largest kinds of slate, are found to lay firm on *battens*, which are, consequently, much employed, and produce a very considerable saving of expense in large buildings. A batten is a narrow portion of deal, about two inches and a half, or three inches wide; four of them being commonly procured from an eleven inch board.

For countess slates, battens three-quarters of an inch thick, will be of adequate substance; but for the larger and heavier kinds, inch battens will be necessary. In battening a roof for slates, the battens are not placed at an uniform distance from each other, but so as to suit the length of the slates; and as these vary as they approach the apex, or ridge of the roof, it follows that the slater himself is the best judge where to fix them, so as best to support the slates.

A roof, to be covered with patent slates, requires that the common rafters be left loose upon their purlines, as they must be so arranged that a rafter shall lie under every one of the meeting-joints. Neither battening nor boarding is required for these slates. The number of rafters will depend on the width of the slates; hence if they be of a large size, very few will suffice. This kind of slating is likewise commenced at the eaves; but no crossing or bonding is required, as the slates are laid uniformly, with each end reaching to the centre of the rafter, and butted up to each other throughout the length of the roof. When the eaves-course is laid, the slates which compose it are screwed down to the rafters by two or three strong inch and half screws at each of their ends. A line is then strained about two inches below the upper edge, in order to guide the laying of the next course, which is laid with its lower edge touching the line. This lining, laying with a lap, and screwed

down, is continued till the roof is completely covered. The joints are then secured by filletting, which consists in covering all the meeting-joints with fillets of slate, bedded in glazier's putty, and screwed down through the whole into the rafters. The fillets are usually about three inches wide, and of a length proportionate to that of the slates, whose joints they have to cover. These fillets are solidly bedded in the putty, and their intersecting joints are lapped similar to those of the slates. The fillets being so laid, and secured by one in the middle of the fillet and one in each lap, are next neatly pointed all round their edges with more putty, and then painted over with the colour of the slate. The hips and ridges of such slating are frequently covered by fillets, which produces a very neat effect; but lead, which is not much dearer, is by far the best kind of covering for all hips and ridges. The patent slating may be laid so as to be perfectly water-tight, with an elevation of the rafters considerably less than for any other slate or tile covering. The rise in each foot of length in the rafter is not required to be more than two inches, which, in a rafter of fifteen feet, will amount to only two feet six inches: a rise scarcely perceptible from the ground.

Slating is performed in several other ways, but the principles already explained, embrace the most of them. Some workmen shape and lay their slates in a lozenge form. This kind of work consists in getting all the slates to an uniform size, of the shape of a geometrical square. When laid on the roof, which must be boarded, they are bonded and lapped as in common slating, observing only to let the elbow, or half of the square, appear above each slate that is next beneath it, and be regular in the courses all over the roof. One nail or screw only can be used for such slating; hence it soon becomes dilapitated. It is commonly employed in places near to the eye, or where particular neatness is required.

It has been ascertained, that a slate one inch thick will, in an horizontal position, support as much, in weight, as five inches of Portland stone similarly suspended. Hence slates are now wrought and used in galleries, and other purposes, where it is essential to have strength and lightness combined.

Slates are also fashioned into chimney-pieces; but are incapable of receiving a polish like marble. It makes excellent skirtings of all descriptions, as well as casings to walls, where dilapidations, or great wear and tear are to be ex-

pected. For these purposes, it is capable of being fixed with joints, equally as neat as wood: and may, if required, be painted over so as to appear like it. Stair-cases may also be executed in slate, which will produce a resemblance of marble.

MENSURATION OF PLASTERERS' AND SLATERS' WORK.

Plasterers' work is executed by the yard square; and the dimensions are taken in feet and inches.

If a room consists of more than four quoins, the additional corners must be allowed at per foot run.

In measuring ceilings with ribs, the superficies must be taken for plain work; then an allowance must be made for each mitre, and the ribs must be valued at so much per foot run, according to the girth; or by the foot superficial, allowing moulding work.

In measuring common work the principal things to be observed are as follow:—first, to make deductions for chimneys, windows, and doors; secondly, to make deductions for rendering upon brick work, for doors and windows; thirdly, if the workman find materials for rendering between quarters, one-fifth must be added for quarters; but if workmanship only is found, the whole must be measured as whole work, because the workman could have performed the whole much sooner if there had been no quarters; fourthly, all mouldings in plaster work are measured by the foot superficial, the same as joiners, by girting over the mouldings with a line.

Slaters' work is measured and reduced into squares, containing 100 feet superficial. If in measuring the slating on a roof, it be hipped on all sides with a flat at top, and the plan of the building be rectangular, add the length and breadth of two adjoining sides of the eaves, and the length and breadth of two adjoining sides at the flat together, multiply the sum by the breadth of the slope, and the product will give the area of the space that is covered. Add the number of square feet produced, by multiplying the girts of the roof by the length of the slates at the eaves; to the area also, for the trouble of putting on the double row of slates, add the number of square feet produced by multiplying the length of the hips by one foot in breadth, and the sum will be the whole contents, and yield a compensation for the trouble and waste of materials. If there be no flats, add the two adjoining sides and twice the length of the ridge for the length; multiply the sum by the breadth of the slips, for

the area of the space covered, and add the allowances as before.

Another plan is to allow in addition to the nett dimensions of the work, six inches for all the eaves, and four inches for the hips.

All faced work in slate skirting, stair-cases, galleries, &c. is charged by the foot superficial, without any addition.

PLUMBING,

Is the art of casting and working in lead, and using the same in the covering and for other purposes in building.

To the plumber is also confided the pump-work, as well as the making and forming of cisterns and reservoirs, large or small closets, &c. for the purposes of domestic œconomy. The plumber does not use a great variety of tools, because the ductility of the metal upon which he operates does not require it.

The tools used, consist of an iron hammer, rather heavier than a carpenter's, with a short thick handle; two or three wooden mallets of different sizes; and a dressing and flatting tool.

This last is of beech, about eighteen inches long, and two inches square, planed smooth and flat on the under surface, rounded on the upper, and one of its ends tapered off round as a handle. With this tool he stretches out and flattens the sheet-lead, or dresses it to the shape required, using first the flat side, then the round one, as occasion may require.

The plumber has also occasion for a jack and trying plane, similar to that of the carpenter.

With this he reduces the edges of sheet-lead to a straight line, when the purposes to which it is to be applied require it.

Also a chalk line, wound upon a roller, for marking out the lead into such breadths as he may want.

His cutting tools consist of a variety of chisels and gouges as well as knives.

The latter of these are used for cutting the sheet lead into slips and pieces after it has been marked out by the chalk line.

Files of different sizes; ladles of three or four sizes, for melting the solder; and an iron instrument called *grozing-irons.*

These grozing-irons are of several sizes, generally about twelve inches in length, tapered at both ends, the handle end being turned quite round, to allow of its being firmly held while in use: the other end is a bulb of a spindle, or spherical shape, of a size proportioned to the soldering intended to be executed. They are, when required for use, heated to redness.

The plumber's measuring rule is two feet in length, divided into three equal parts of eight inches each; two of its legs are of box-wood, duodecimally divided; and the third consists of a piece of slow tempered steel, attached to one of the box legs by a pivot on which it turns, and falls, when not in use, into a groove cut in such leg for its reception. This steel leg can be passed into places where the others cannot enter; and it is also useful for occasionally removing the oxide or any other extraneous matters from the surface of the heated metal.

Scales and weights are also necessary; and he must be supplied with centre-bits of all sizes; and a stock to work them, for the purpose of making perforations in lead or wood, through which he may want to insert pipes, &c. Compasses, to strike circular pieces, to line or cover figures of that shape, are occasionally required.

Lead is obtained from ore, and, from its being generally combined with sulphur, it has been denominated "*sulphuret.*" After the ore has been taken from its bed it is smelted, first being picked, in order to separate the unctuous and rich, or genuine ore from the stony matrix, and other impurities; the picked ore is then pounded under stampers worked by machinery, and afterwards washed to carry off the remainder of the matrix, which could not be separated in picking. It is next put into a reverberatory furnace, to be *roasted;* during which operation, it is repeatedly stirred, to facilitate the evaporation of the sulphur. When the surface begins to assume the appearance of a paste, it is covered with charcoal, and well shaken together: the fire is then increased, and the purified lead flows down on all sides into the basin of the furnace, whence it runs off into moulds prepared for its reception. The moulds are capable of receiving 154lbs. of lead each, and their contents, when cool, are, in the commercial world, called ***pigs***.

Lead is of a bluish-white colour, and when newly melted, or cut, is quite bright; but it soon becomes tarnished on exposure to the atmosphere; assuming first a dirty grey colour, and afterwards becomes white. It is capable of

being hammered into very thin plates, and may be drawn into wire; but its tenacity is very inferior to that of other metals; for a leaden wire, the hundred and twentieth part of an inch in diameter, is only capable of supporting about 18lb. without breaking. Lead, next to tin, is the most fusible of all metals; and if a stronger heat be applied, it boils and evaporates. If cooled slowly, it crystallizes. The change of its external colour is owing to its gradual combination with oxygen, which converts its exterior surface into an oxyd. This outward crust, however, preserves the rest of the metal for a long time, as the air can penetrate but very slowly.

Lead is not acted upon immediately by water, though that element greatly facilitates the action of the air upon it: for it is known that, when lead is exposed to the atmosphere, and kept constantly wet, the process of oxidation takes place much more rapidly than it does under other circumstances: hence the white crust that is to be observed on the sides of leaden vessels containing water, just at the place where the surface of the water terminates.

Lead is purchased by plumbers, in *pigs*, and they reduce it into sheets or pipes, as they have occasion. Of sheet-lead they have two kinds, cast and milled. The former is used for covering flat roofs of buildings, laying of terraces, forming gutters, lining reservoirs, &c.; and the latter, which is very thin, for covering the hips and ridges of roofs. This last they do not manufacture themselves, but purchase it of the lead merchants, ready prepared.

For the casting of sheet lead, a copper is provided, and well fixed in masonry, at the upper end of the workshop, near the mould or casting table, which consists of strong deal boards, well jointed together, and bound with bars of iron at the ends. The sides of this table, of which the shape is a parallelogram, vary in size from four to six feet in width, and from 16 to 18 feet and upwards in length, and are guarded by a frame or edging of wood, 3 inches thick, and 4 or 5 inches higher than the interior surface, called the *shafts*, This table is fixed upon firm legs, strongly framed together, about 6 or 7 inches lower than the top of the copper. At the upper end of the mould, nearest the copper, is a box, called the *pan*, which is adapted in its length to the breadth of the table, having at its bottom a long horizontal slit, from which the heated metal is to issue, when it has been poured in from the copper. This box moves upon rollers along the surface of the rim of the table, and is put in mo-

tion by means of ropes and pulleys, fixed to beams above. While the metal is melting, the surface of the mould, or table, is prepared by covering it with a stratum of dry and clean sand, regularly smoothed over with a kind of rake, called a *strike*, which consists of a board about 5 inches broad, and rather longer than the inside of the mould, so that its ends, which are notched about two inches deep, may ride upon the shafts. This being passed down the whole length of the table, reduces the sand to an uniform surface. The pan is now brought to the head of the table, close to the copper, its sides having previously been guarded by a coat of moistened sand, to prevent its firing from the heat of the metal, which is now put in by ladles from the copper.

These pans, or boxes, it must be observed, are made to contain the quantity of melted lead which is required to cast a whole sheet at one time; and the slit in the bottom is so adjusted as to let out, during its progress along the table, just as much as will completely cover it of the thickness and weight per foot required. Every thing being thus prepared, the slit is opened, and the box moved along the table, dispensing its contents from the top to the bottom, and leaving in its progress a sheet of lead of the desired thickness. When cool, the sheet is rolled up and removed from the table, and other sheets are cast, till all the metal in the copper is exhausted. The sheets thus formed are then rolled up and kept for use.

In some places, instead of having a square box upon wheels, with a slit in the bottom, the pan consists of a kind of trough, being composed of two planks nailed together at right angles, with two triangular pieces fitted in between them, at their ends. The length of this pan, as well as that of the box, is equal to the whole breadth of the mould. It is placed with its bottom on a bench at the head of the table leaning with one side against it: to the opposite side is fixed a handle, by which it may be lifted up in order to pour out the liquid metal. On the side of the pan next the mould are two iron hooks, to hold it to the table, and prevent it from slipping while the metal is being poured into the mould.

The mould, as well as the pan, is spread over, about two inches thick, with sand, sifted and moistened, and rendered perfectly level by moving over it the strike, and smoothing it down with a plane of polished brass, about a quarter of an inch thick, and nine inches square, turned up on the edges.

Before they proceed to casting the lead, the strike is made

ready by tacking two pieces of old hat on the notches, or by covering the notches with leather cases, so as to raise the under side of the strike, about an eighth of an inch, or more, above the sand, according to the proposed thickness of the sheet. The face or under side of the strike is then smeared with tallow, and laid across the breadth of the mould, with its ends resting on the shafts. The melted lead is then put into the pan with ladles; and, when a sufficient quantity has been put in, the scum is swept off with a piece of board, and suffered to settle on the coat of sand, to prevent its falling into the mould, when the metal is poured out. It generally happens, that the lead, when first taken from the copper, is too hot for casting; it is therefore suffered to cool in the pan, till it begins to stand with a shell or wall on the sand with which the pan is lined. Two men then take the pan by the handle, or one of them takes it by means of a bar and chain fixed to a beam in the ceiling, and turn it down, so that the metal runs into the mould: while another man stands ready with the strike, and, as soon as all the metal is poured in sweeps it forward and draws the residue into a trough at the bottom, which has been prepared to receive it. The sheet is then rolled up, as before.

In this mode of operation, the table inclines in its length about an inch, or an inch and a half, in the length of sixteen or seventeen feet, or more, according to the required thickness of the sheets; the thinner the sheet the greater the declivity; *and vice versâ*. The lower end of the mould is also left open, to admit of the superfluous metal being thrown off.

When a cistern is to be cast, the size of the four sides is measured out; and the dimensions of the front having been taken, slips of wood, on which the mouldings are carved, are pressed upon the sand. Figures of birds, beasts, &c. are likewise stamped in the internal area, by means of leaden moulds. If any part of the sand has been disturbed in doing this, it is made smooth, and the process of casting goes on as for plain sheets; except that, instead of rolling up the lead when cast, it is bent into four sides, so that the two ends, when they are soldered together, may be joined at the back; the bottom is afterwards soldered up.

The lead which lines the Chinese tea-boxes is reduced to a thinness which our plumbers cannot, it is said, approach. The following account of the process was communicated by an intelligent East-Indian, in a letter which appeared in the Gentleman's Magazine. "The caster sits by

a pot, containing the melted metal, and has two large stones, the lower one fixed and the upper one movable, having their surfaces of contact ground to each other, directly before him. He raises the upper stone by pressing his foot upon its side, and with an iron ladle pours into the opening a sufficient quantity of the fluid metal. He then lets fall the upper stone, and thus forms the lead into an extremely thin and irregular plate, which is afterwards cut into its required form."

Cast sheet lead, used for architectural purposes, is technically divided into 5lb. 5½lb. 6lb. 6½lb. 7lb. 7½lb. 8lb. and 8½lb.; by which is understood, that every superficial foot is to contain those respective weights, according to the price agreed upon.

The milled lead used by plumbers is very thin, seldom containing more than 5lb. to the foot. It is by no means adapted to gutters or terraces, nor, indeed, to any part of a building that is much exposed either to great wear or to the effects of the sun's rays: in the former case, it soon wears away; in the latter, it expands and cracks. It is laminated in sheets of about the same size as those of cast lead, by means of a roller, or flatting-mill.

Lead-pipes, besides the various ways of manufacture described in page 362, are sometimes made of sheet lead, by beating it on round wooden cylinders of the length and dimensions required, and then soldering up the edges.

Solder is used to secure the joints of work in lead, which by other means would be impossible. It should be easier of fusion than the metal intended to be soldered, and should be as nearly as possible of the same colour. The plumber therefore uses, what is technically called, *soft solder*, which is a compound of equal parts of tin and lead, melted together and run in to moulds. In this state it is sold by the manufacturer by the pound.

In the operation of soldering, the surfaces or edges intended to be united are scraped very clean, and brought close up to each other, in which state they are held by an assistant, while the plumber applies a little resin on the joints, in order to prevent the oxidation of the metal. The heated solder is then brought in a ladle and poured on the joint; after which it is smoothed and finished by rubbing it about with a red-hot soldering iron, and when completed is made smooth by filing.

In the covering of roofs or terraces with lead, (the sheets never exceeding six feet in breadth,) it becomes necessary in

large surfaces, to have joints; which are managed several ways, but in all, the chief object is to have them water-tight. The best plan of effecting this, is to form *laps* or roll joints, which is done by having a roll, or strip of wood, about two inches square, but rounded on its upper side, nailed under the joints of the sheets, where the edges lap over each other; one of these edges is to be dressed up over the roll on the inside, and the other is to be dressed over them both on the outside, by which means the water is prevented from penetrating. No other fastening is requisite than what is required from the hammering of the sheets together down upon the flat; nor should any other be resorted to, when sheet lead is exposed to the vicissitudes of the weather; because it expands and shrinks, which, if prevented by too much fastening, would cause it to crack and become useless. It sometimes, however, occurs, that rolls cannot be used, and then the method of joining by *seams* is resorted to. This consists in simply bending the approximate edges of the lead up and over each other, and then dressing them down close to the flat, throughout their length. But this is not equal to the roll, either for neatness or security.

Lead flats and gutters should always be laid with a current, to keep them dry. About a quarter of an inch to the foot run is a sufficient inclination.

In laying gutters, &c. pieces of milled-lead, called *flashings*, about eight or nine inches wide, are fixed in the walls all round the edges of the sheet-lead, with which the flat is covered, and are suffered to hang down over them, so as to prevent the passage of rain through the interstice between the raised edge and the wall. If the walls have been previously built, the mortar is raked out of the joint of the bricks next above the edge of the sheet, and the flushings are not only inserted into the crack at the upper sides, but their lower edges are likewise dressed over those of the lead in the flat, or gutter. When neither of these modes can be resorted to, the flushings are fastened by wall-hooks, and their lower edges dressed down as before.

Drips in flats, or gutters, are formed by raising one part above another, and dressing the lead, as already described, for covering the rolls. They are resorted to when the gutter or flat, exceeds the length of the sheet; or sometimes for convenience. They are also an useful expedient to avoid soldering the joints.

Sheet lead is also used in the lining of reservoirs, which

are made either of wood or masonry. As these conveniences are seldom in places subject to material change of temperature, recourse may be had to the soldering, without fear of its damaging the work, by promoting a disposition to crack.

The pumps which come under the province of the plumber, are confined generally to two or three kinds, used for domestic purposes, of which the suction and lifting pumps are the chief: these, as well as water-closets, are manufactured by a particular set of workmen, and sold to the plumber, who furnishes the lead pipes, and fixes them in their places.

Plumber's work is generally estimated by the pound, or hundred weight; but the weight may be discovered by measurement, in the following manner: sheet-lead used in roofing and guttering is commonly between seven and twelve pounds to the square foot; but the following table exhibits the particular weight of a square foot for each of the several thicknesses.

Thickness.	Pounds to a sqr. ft.	Thickness.	Pounds to a sqr. ft.
.10	5.899	.15	8.848
.11	6.489	.16	9.438
$\frac{1}{9}$	6.554	$\frac{1}{6}$	9.831
.12	7.078	.17	10.028
$\frac{1}{8}$	7.373	.18	10.618
.13	7.668	.19	11.207
.14	8.258	$\frac{1}{5}$	11.797
$\frac{1}{7}$	8.427	·21	12.387

In this table the thickness is set down in tenths and hundredths, &c. of an inch; and the annexed corresponding numbers are the weights in avoirdupois pounds, and thousandth parts of a pound; so that the weight of a square foot of 1-10th of an inch thick, 10-100ths, is 5 lbs. and 899 thousandth parts of a pound; and the weight of a square foot 1-9th of an inch in thickness, is 6 pounds and 554 thousandths of a pound. Leaden pipe of an inch bore, is commonly 13 or 14 lbs. to the yard in length.

GLAZING.

The business of this class of artificers consists in putting glass into sashes and casements. Glazier's work may be classed under three distinct heads, sash-work, lead-work, and fret-work.

The tools requisite for the performance of the first of these departments are, a diamond, a ranging lath, a short lath, a square, a rule, a glazing-knife, a cutting-chisel, a beading-hammer, a duster, and sash-tool; and in addition, for stopping in squares, a hacking-knife and hammer.

The diamond is a speck of that precious stone, polished to a cutting point, and set in brass on an iron socket, to receive a wooden handle, which is so set as to be held in the hand in the cutting direction. The top of the handle goes between the root of the fore-finger and the middle finger, and the hinder part, between the point of the fore-finger and thumb; there is, in general, a notch in the side of the socket, which should be held next to the lath. Some diamonds have more cuts than one. Plough diamonds have a square nut on the end of the socket, next the glass, which, on running the nut square on the side of the lath, keeps it in the cutting direction.

Glass binders have these plough diamonds without long handles, as, in cutting their curious productions, they cannot apply a lath, but direct them by the point of their middle finger, gliding along the edge of the glass.

The ranging lath must be long enough to extend rather beyond the boundary of the table of glass.

Ranging of glass is the cutting it in breadths as the work may require, and is best done by one uninterrupted cut from one end to the other.

The square is used in cutting the squares from the range, that they may with greater certainty be cut at right angles. The glazing knife is used for laying in the putty in the rebates of the sash, for binding in the glass, and for finishing the front putty.

Of the glass used in building, three qualities are in common use, denominated *best*, *second*, and *third*.

The best is that which is the purest metal and free of blemishes, as blisters, specks, streaks, &c.; the second is inferior, from its not being so free from these blemishes; and the third are still inferior, both in regard to quality and colour, being of greener hue.

They are all sold at the same price per crate; but the number of tables varies according to the quality. Best twelve, second fifteen, and third eighteen tables.

These tables are circular when manufactured, and about four feet in diameter, having in the centre a knot, to which, in the course of the process, the flashing rod was fixed; but for the safety of carriage, and convenience of handling, as

well as utility in practice, a segment is cut off about four inches from the knot. The large piece with the knot, stil retains the name of *table;* the smaller piece is technically called *a slab.* From these tables being of a given size, it is reasonable to suppose that, when the dimensions of squares are such as cut the glass to waste, the price should be advanced.

A superior kind of glass may be obtained at some of the first houses in London, which is very flat, and of large dimensions; some of it being 2 feet 8 inches by 2 feet 1 inch; these are sold only in squares.

Rough glass is well adapted to baths, and other places of privacy; one side is ground with emery or sand, so that no objects can be seen through it, though the light be still transmitted.

The glass, called *German-sheet,* is of a superior kind, as it can be had of much larger dimensions than common glass; it is also of a purer substance, and for these reasons, is frequently appropriated to picture frames. Squares may be had at the astonishing size of 3 feet 8 inches, by 3 feet 1 inch, and 3 feet 10 inches by 2 feet 8 inches, and under.

The glass is first blown in the form of a globe, and afterwards flatted in a furnace, in consequence of which it has a very forbidding appearance from the outside, the surface being uneven.

Plate-glass is the most superior in quality, substance, and flatness, being cast in plates, and polished. The quantity of metal it contains, must be almost, if not altogether, colourless; that sort which is tinged being of an inferior quality. Plate-glass when used in sashes, is peculiarly magnificent; and it can be had of larger dimensions than any other kind of glass.

Stained-glass is of different colours, as red, orange, yellow, green, blue, and purple.

These colours are fixed by burning, and are as durable as the glass.

Glass can be bent to circular sweeps, which is much used in London for shop windows, and is carried to great perfection in covers, for small pieces of statuary, &c.

The application of stained glass to the purposes of glazing is called *fret-work.* This description of work consists of working ground and stained glass, in fine lead, into different patterns. In many cases family arms and other devices are worked in it. It is a branch capable of great improvement; but at present is much neglected. Old pieces are very much

esteemed, though the same expense would furnish elegant modern productions. They are placed in halls and staircase windows, or in some particular church windows. In many instances they are introduced where there is an unpleasant aspect, in a place of particular or genteel resort.

Lead-work is used in inferior offices, and is in general practice all through the country. Frames intended to receive these lights are made with bars across, to which the lights are fastened by leaden bars, called saddle bars; and where openings are wanted, a casement is introduced either of wood or iron. Sometimes a sliding frame answers the same purposes. Church windows are generally made in this manner, in quarries or in squares.

The tools with which this work is performed are, in addition to the foregoing, as follow:—

A *vice*, with different cheeks and cutters, to turn out the different kinds of lead as the magnitude of the window or the squares may require.

The German vices, which are esteemed the best, are furnished with moulds, and turn out lead in a variety of sizes. The bars of lead cast in these vices are received by the mill, which turns them out with two sides parallel to each other, and about $\frac{3}{8}$ of an inch broad, with a partition connecting the two sides together, about $\frac{1}{8}$ of an inch wide, forming on each side a groove, nearly $\frac{2}{61}$ by $\frac{1}{8}$ of an inch, and about 6 feet long.

Besides a vice and moulds there are a *setting-board, latterkin, setting-knife, resin-box tin, glazing-irons*, and *clips*.

The *setting-board* is that in which the ridge of the light is marked and divided into squares, struck out with a chalk line, or drawn with a lath, which serves to guide the workmen. One side and end is squared with a projecting bead or fillet.

The *latterkin* is a piece of hard wood pointed, to run in the groove of the lead, and widen it for the easier reception of the glass.

The *setting-knife* consists of a blade with a round point, loaded with lead at the bottom and terminating in a long square handle. The square end of the handle serves to force the square of glass tight in the lead. All the intersections are soldered on both sides, except the outside joints of the outer sides, that is, where they come to the outer edge. These lights should be cemented by pouring thin paint along the lead bars, and filling up the chasms with dry whiting, to which, after the oil in the paint has se-

creted a little, a little more dry whiting, or white lead, must be added. This will dry hard, and resist the action of the atmosphere.

MENSURATION OF GLAZIERS' WORK.

Glaziers' work is measured by superficial feet, and the dimensions are taken in feet, tenths, &c. For this purpose, their rules are generally divided into decimal parts, and their dimensions squared according to decimals. Circular, or oval windows are measured as if they were rectangular; because in cutting squares of glass there is a very great waste, and more time is expended than if the window had been of a rectangular form.

PAINTING,

As applied to purposes of building, is the application of artificial colours, compounded either with oil or water, in embellishing and preserving wood, &c.

This branch of painting is termed *economical*, and applies more immediately to the power which oil and varnishes possess, of preventing the action of the atmosphere upon wood, iron, and stucco, by interposing an artificial surface; but it is here intended to use the term more generally, in allusion to the decorative part, and as it is employed by the architect, throughout every part of his work, both externally and internally.

In every branch of painting in oil, the general processes are very similar, or with such variations only, as readily occur to the workman.

The first coatings, or layers, if on wood or iron, ought always to be of ceruse or white lead, of the best quality, previously ground very fine in nut or linseed oil, either over a stone with a muller, or, as that mode is too tedious for large quantities, passed through a mill. If used on shutters, doors, or wainscottings, made of fir or deal, it is very requisite to destroy the effects of the knots; which are generally so completely saturated with turpentine, as to render it, perhaps, one of the most difficult processes in this business. The best mode, in common cases, is, to pass a brush over the knots, with ceruse ground in water, bound by a size made of parchment or glue; when that is dry, paint the knots with white lead ground in oil, to which add some powerful siccative, or dryer, as red lead, or litharge of

lead; about one-fourth part of the latter. These must be laid very smoothly in the direction of the grain of the wood.

When the last coat is dry, smooth it with pumice-stone, or give it the first coat of paint, prepared or diluted with nut or linseed oil; after which, when sufficiently dry, all the nail-holes or other irregularities on the surface, must be carefully stopped with a composition of oil and Spanish white, commonly known by the name of putty. The work must then be again painted with white lead and oil, somewhat diluted with the essence of oil of turpentine, which process should, if the work be intended to be left of a plain white, or stone colour, be repeated not less than three or four times; and if of the latter colour, a small quantity of ivory or lamp-black should be added. But if the work is to be finished of any other colour, either grey, green, &c. it will be requisite to provide for such colour, after the third operation, particularly if it is to be finished flat, or, as the painters style it, dead white, grey, fawn, &c. In order to finish the work flatted or dead, which is a mode much to be preferred for all superior works, not only for its appearance, but also for preserving the colour and purity of the tint, one coat of the flatted colour, or colour mixed up with a considerable quantity of turpentine, will be found sufficient; although in large surfaces it will frequently be requisite to give two coats of the flatting colour, to make it quite complete. Indeed, on stucco it will be almost a general rule.

In all the foregoing operations, it must be observed that, some sort of dryer is absolutely requisite; a very general and useful one is made by grinding in linseed, or, perhaps, prepared oils boiled are better, about two parts of the best white copperas, which must be well dried with one part of litharge of lead: the quantity to be added, will much depend on the dryness or humidity of the atmosphere, at the time of painting, as well as the local situation of the building. It may here be noticed, that there is a sort of copperas made in England, and said to be used for some purposes in medicine, that not only does *not* assist the operation of drying in the colours, but absolutely prevents those colours drying, which would otherwise have done so in the absence of this copperas.

The best dryer for all fine whites, and other delicate tints, is sugar of lead, ground in nut oil, but being very active, a small quantity, about the size of a walnut, will be sufficient for twenty pounds of colour, when the basis is white lead.

It will be always necessary to caution painters to keep their utensils, brushes, &c. very clean, as the colour would otherwise soon become very foul, so as to destroy the surface of the work. If this should happen, the colour must be passed through a fine sieve, or canvass, and the surface of the work be carefully rubbed down with sand-paper, or pumice-stone: the latter should be ground in water, if the paint be tender, or recently laid on. The above may suffice as to painting on wood, either on inside or outside work, the former being seldom finished otherwise than in oil: four or five coats are generally sufficient.

It does not appear that painting in oil can be serviceable in stucco, unless the walls have been erected a sufficient time to permit the mass of brick-work to have acquired a sufficient degree of dryness. When stucco is on battened work, it may be painted over much sooner than when prepared on brick. Indeed, the greatest part of the art of painting stucco, so as to stand or wear well, consists in attending to these observations, for whoever has observed the expansive power of water, not only in congelation, but also in evaporation, must be well aware that when it meets with any foreign body, obstructing its escape, as oil painting, for instance, it immediately resists it, forming a number of vesicles or particles, containing an acrid lime-water, which forces off the layers of plaster, and frequently causes large defective patches, not easily to be eradicated.

Perhaps, in general cases, where persons are building on their own estates, or for themselves, two or three years are not too long to suffer the stucco to remain unpainted, though frequently, in speculative works, as many weeks are scarcely allowed to pass.

The foregoing precautions being attended to, there can be no better mode adopted for priming, or laying on the first coat on stucco, than by linseed or nut-oil, boiled with dryers, as before mentioned; taking care, in all cases, not to lay on too much, so as to render the surface rough and irregular, and not more than the stucco will absorb. It should then be covered with three or four coats of white-lead, prepared as described for painting on wainscotting, allowing each coat a sufficient time to dry hard. If time will permit, two or three days between each layer, will be advantageous. When the stucco is intended to be finished in any given tint, as grey, light green, &c. it will then be proper, about the third coat of painting, to prepare the ground for such tint, by a slight advance towards it. Grey is made

with white-lead, Prussian-blue, ivory-black, and lake; sage-green, pea, and sea-greens, with white, Prussian-blue, and fine yellows; apricot and peach, with lake, white, and Chinese vermilion; fine yellow fawn colour with burnt terra sienna, or umber and white; and olive-greens with fined Prussian-blues, and Oxfordshire ochre.

Distemper, or painting in water colours, mixed with size, stucco, or plaster, which is intended to be painted in oil when finished, but not being sufficiently dry to receive the oil, may have a coating in water colours, of any given tint required, in order to give a more finished appearance to that part of the building. Straw colours may be made with French whites and ceruse, or white lead and masticot, or Dutch pink. Greys, full, with some whites and refiner's verditer. An inferior grey may be made with blue-black, or bone-black and indigo. Pea-greens with French green, Olympian green, &c. Fawn-colour with burnt terra de sienna, or burnt umber and white, and so of any intermediate tint. The colours should all be ground very fine, and mixed with whiting and a size made with parchment, or some similar substance. Less than two coats will not be sufficient to cover the plaster, and bear out with an uniform appearance. It must be recollected, that when the stucco is sufficiently dry, and it is desirable to have it painted in oil, the whole of the water-colours ought to be removed, which may easily be done by washing, and when quite dry, proceed with it after the direction given on oil-painting in stucco.

If old plastering has become disfigured by stains, or other blemishes, and it be desired to have it painted in distemper, it is, in this case, advisable to give the old plastering, when properly cleaned off and prepared, one coat, at least, of white-lead ground in oil, and used with spirits of turpentine, which will generally fix old stains; and, when quite dry, take water-colours very kindly.

MENSURATION OF PAINTERS' WORK

Painters' work is measured by the yard square, and the dimensions are taken in feet, inches, and tenths. Every part which the brush has passed over is measured, consequently the dimensions must be taken with a line, that girts over the mouldings, breaks, &c. All kinds of ornamental work produces an extra price, according to the nature of the imitations, &c. Carved work is also valued according to the time taken in painting it.

APPENDIX.

RAIL-ROADS

AND

LOCOMOTIVE ENGINES.

AMIDST the various speculations of the day, perhaps none have more deservedly excited the public interest than that of the numerous projected lines of rail-road for diminishing the friction of carriages, and for propelling carriages on them by either gas or steam power.

The lessening the friction, produces a consequent diminution in the power which otherwise would be required to propel a given weight; and therefore, is, in a commercial nation, like that of the united kingdom, a subject worthy of the highest consideration.

Railways were originally made of wood, and appear to have been first introduced between the river Tyne and some of the principal coal-pits, as early as the year 1680. The scarcity of this material, and the expense of frequent repairs, soon suggested an idea that iron might be more advantageously employed. At first, flat rods of bar-iron were nailed upon the original wooden rails, or, as they were technically called, *sleepers;* which, though an expensive process, was found to be a great improvement. But as the wood on which these rested was liable to rot and give way, these railings were soon after superseded by others made entirely of iron.

These *tram* or *rail-roads* have, for a considerable length of time, been much used in the colliery and mining districts; and some few have been carried from one town or manufacturing district to another. The principal of these latter in England and Wales are, the Cardiff and Merthyr, 26¾ miles long, running near the Glamorganshire canal; the Caermarthen; the Lexhowry, 28 miles, in the counties of Monmouth and Brecknock; the Surrey 26 miles; the Swansea, 7½ miles; one between Gloucester and Cheltenham; besides several in the north of England.

Railways are of two kinds, arising from the disposition of

the flanch that is to guide the wheels of the carriage, and prevent it from running off the rail. In the one, the flanch is at right angles, and of one piece with the flat surface of the rail: in the other, the flat surface of the rail is raised above the level of the ground, and the flanch is fixed on the wheel of the carriage, at right angles to the tyre, or iron placed on the circumference of the wheel, to strengthen it. Beside these, another kind of railway has lately been introduced by Mr. Palmer, which consists of a single rail, supported some height from the surface of the ground: on this, two wheels confined in sufficient frame-work, are placed, suspending the load equally balanced on either side. This arrangement certainly seems to ensure the grand principle of lessening friction, and doubtless will, in many situations, be found a great improvement.

Previously to entering upon the probable advantages likely to result from a general introduction of railways, we shall give the substance of the specification of a patent, obtained in Sept. 1816, by Messrs. Losh and Stephenson, both of whom are well known to those interested in the subject.

These gentlemen preface a description of their method of facilitating carriages along tram and railways, with an observation, that there are two kinds of railways in general use; the one consisting of bars of cast iron, generally of the shape of that described by *a*, fig.631, the other of the shape of that described by figs. 630 and 631. That shewn at *a*, fig. 629, is known in different situations by the denomination of the edge rail, round-top rail, fish-backed rail, &c. That shewn at figs. 632 and 633, by the denomination of the plate-rail, tram-way plate, barrow-way plate, &c. The first we shall distinguish by the name of the edge railway; the second, by that of the plate railway.

In the construction of edge railways, Messrs. Losh and Stephenson's objects are, first, to fix both the ends of the rails, or separate pieces, of which the ways are formed, immovable, in or upon the chairs or props by which they are supported; secondly, to place them in such a manner, that the end of any one rail shall not project above or fall below the correspondent end of that with which it is in contact, or with which it is joined; thirdly, to form the joinings of the rails, with the pedestals or props which support them, in such a manner, that if these props should vary from their perpendicular position in the line of the way, (which in other railways is often the case) the joinings of the rails with each other would remain as before such varia-

tion, and so that the rails shall bear upon the props as firmly as before. The formation of the rails or plates of which a plate railway consists, being different from the rails of which the edge railways are composed, they are obliged to adopt a different manner of joining them, both with each other, and with the props and sleepers on which they rest. But in the joining these rails or plates upon their chairs and sleepers, they fix them down immovably, and in such a manner that the end of one rail or plate does not project above, or fall below the end of the adjoining plate, so as to present an obstacle, or cause a shock to the wheels of the carriages which pass over them, and they also form the joinings of these rails or plates in such a manner as to prevent the possibility of the nails, which are employed in fixing them in their chairs, from starting out of their places from the vibration of the plates, or from other causes.

In what relates to the locomotive engines and their carriages, which may be employed for conveying goods or materials along edge railways or plate-railways, or for propelling or drawing after them the carriages or waggons employed for that purpose, their invention consists in sustaining the weight, or a proportion of the weight, of the engine, upon pistons, movable within cylinders, into which the steam or the water of the boiler is allowed to enter in order to press upon such pistons; and which pistons are, by the intervention of certain levers and connecting rods, or by any other effective contrivance, made to bear upon the axles of the wheels of the carriage upon which the engine rests. In the formation of the wheels it is their object to construct them in such a manner, and to form them of such materials, as shall make them more durable and less expensive in the repairs than those hitherto in use. This is accomplished by forming the wheels either with spokes of malleable iron, and with cast iron rims, or by making the wheels and spokes of cast iron, with hoops, tyres, or trods, of malleable iron, and in some instances, particularly for wheels of very small diameters, instead of spokes of malleable iron, employing plates of malleable iron, to form the junction between the naves and the cast iron rims of the wheels.

The advantages gained by this method of constructing railways are, first, that the separate pieces of which they consist are, *cæteris paribus*, rendered by this mode of joining them, capable of sustaining a much heavier pressure than those which are joined in the usual way. Secondly, by this

mode of joining the rails, they remove the liability to which rails joined in the usual plan, (where the end of one rail is seldom in the same plane with the correspondent end of the next) are exposed, of receiving blows and shocks from the carriages which move over them, and to which blows and shocks the great breakage which often occurs in railways, when not made of enormous weight, may generally be referred; and as action and re-action are mutual and contrary, if they prevent the communication of shocks to the rails, they at the same time preserve the wheels, the carriages, and engines which move over them, from the re-action which is often destructive to them. As the centre of gravity in a loaded coal-waggon is, from its shape, much elevated, there is generally a great waste of coal from the shaking of the waggons, to which that circumstance (the position of the centre of gravity) makes them more liable when they encounter obstacles, as they do at the junction of almost every two rails on the common railways. On Losh and Stephenson's railways, the loss thus arising is, if not entirely prevented, at least considerably diminished, by the steady and regular motion of the waggons. The usual method of fixing down the plates, of which the plate railways employed in coal-mines, and there called tram and rolley-ways, are formed, is by a single nail, nearly at each end of each plate; which nail passes through a hole in the plate, and fixes it to a sleeper of wood. These nails, from the vibration of the plate, or the motion of the sleeper, or some other cause, generally very soon start up, and consequently the plates work loose, and very frequently the nails come entirely out. The delay of work, the breakage of plates, wheels, &c. and the injury which the horses receive from the loose nails which result from the mode of fixing the plate railways, are generally complained of, and therefore the advantages of a plan which will remove these inconveniences must be apparent.

When locomotive steam-engines are employed as the moving or propelling power on railways, these gentlemen have, from much practice, found it of the utmost importance, that they should move steadily, and as free as possible from shocks or vibrations, which have the effect of deranging the working parts of the machinery, and lessening their power. It is therefore to produce that steadiness of motion, and to prevent the engines from receiving shocks, and to preserve their equilibrium, that they employ the floating pistons, which, acting on an elastic fluid, produce

the desired effect with much more accuracy than could be obtained by employing the finest springs of steel to suspend the engine. The wheels which are constructed on this plan will be found, when compared with those already in use (the weights of both being equal) to be more durable; for the arms, when made of malleable iron, being infinitely less liable to be broken by shocks or concussions, than those of cast iron, may be of less weight, and in fewer numbers, so that the excess of weight of the extra arms of the cast iron wheels may be applied on the rims of these wheels, and thus add to the substance of that part which alone suffers from the friction of the rails. The rims of wheels thus constructed, can also be case-hardened without risk of breaking, either in cooling or afterwards, which is not the case when wheels are cast in one piece. The advantage of hooping cast iron wheels with malleable iron tyres or trods, is, that when such tyres or trods are worn through, they can very easily be replaced at a small expense, and that the tyre, which is not liable to break, receiving the shocks from the re-action of the rails, preserves the cast-iron wheel, by considerably lessening the effect of such shocks on the cast metal.

As it is perhaps impossible to cast the bars or plates of metal of which railways and plate-ways are composed perfectly straight, and correctly even and smooth on their surfaces, and equally difficult to fit the joints with mathematical accuracy, the wheels of the engines and waggons will always have some inequalitics and obstacles to encounter. From these circumstances, therefore, Messrs. Losh and Stephenson are induced to employ the improvements which they have made in the construction of the locomotive engine, and in the wheels of carriages upon edge railways and plate railways, constructed according to their own plans; but it is apparent that their adoption on the rail and plate-ways on the usual construction, is of still more importance.

They therefore claim as a method of facilitating the conveyance of goods, and all manner of materials along edge railways or plate railways, the use of any of the plans they have described singly, as well as the whole of them collectively. They have no hesitation in saying, that on a railway constructed on their plan, and with a locomotive engine and carriage-wheels on their principle, the expedition with which goods can be conveyed with safety, will be increased to nearly double the rate with which they are

at present usually taken along railways, and with less interruption from the breakage of wheels, rails, &c. than at present occurs, and with much less injury to the working parts of the engine.

In order that their specification may be more clearly understood, we have annexed a schedule of drawings.

Fig. 629 represents a longitudinal view of the locomotive engine on the edge railway. *a a a*, are the cylinders containing the floating pistons *b b*, which are more fully described in the next figure.

Fig. 630 represents a cross section of Fig. 629, at the middle cylinders *a*, *a*; *b b* are the floating pistons, connected with the wrought iron rods *c c*, the ends of which rest upon the bearing brasses of the axles of the wheels *d d*. These pistons press equally on all the axles, and cause each of the wheels to press with an equal stress upon the rails, and to act upon them with an equal degree of friction, although the rails should not all be in the same plane, for the bearing brasses have the liberty of moving in a perpendicular direction in a groove or slide, and, carrying the axles and wheels along with them, force the wheels to accommodate themselves to the inequalities of the rail-way.

Fig. 634, is a view of the wheel, with wrought iron arms. *a a a a a a* show how the arms are cast in the nave *b b*, and dropped into the mortise holes *c c c c c c* in the rim, which are dovetailed, to suit the dovetailed ends of the arms *d d d d d d*. The arms are heated redhot previously to dropping them into the holes, in order to cause them to extend sufficiently for that purpose, for when cold they are too short. In doing this they take advantage of that quality which iron possesses of expanding on the application of heat, and of contracting again to its former dimensions on cooling down to the same temperature from which it was raised; the arms, therefore, on cooling are drawn with a force sufficient to produce a degree of combination between their dovetailed ends and the mortises of the rim, which prevents the possibility of their working loose; they are afterwards keyed up; the mortise holes are also dovetailed, from the tail side of the wheel (*a a*, fig. 635) to the crease side (*b b*, on the same figure).

Fig 635, is a cross section through the centre of the wheel, with wrought iron arms.

Fig. 636 is an end view of Fig. 635.

Fig. 637 represents a view of their edge railway; shewing a rail *a*, connected with the two adjoining rails, the ends of which are shewn by *b b*, and also with the props or pedestals on which they rest. *d d* show the metal chairs, and *c c* the stone supports. The joints *e e* are made by the ends of the rails being applied to each other by what is denominated a half lap, and the pin or bolt *g*, which fixes them to each other, and to the chair in which they are inserted, is made to fit exactly a hole which is drilled through the chair, and both ends of the rails at such a height as to allow both ends of the rails to bear on the chair, and the bearance being the apex of a curve, they both bear at the same point. Thus the end of one rail cannot rise above that of the adjoining one; for although the chair may move on the pin in the direction of the line of the road, yet the rails will still rest upon the curved surface of their bearance without moving.

Fig. 638 is a cross section of their edge railway through the middle of one of the chairs *a*, and across the ends of the two adjoining rails *c d* and he pin *e*; *f* is the stone support or sleeper.

Fig. 639 is a cross section of a rail *a*, at the centre, and shows the carriage *c* behind.

Fig. 640 is a plan of the rail-way described at fig. 637, shewing tLe half lap joinings of the rails *c c*, placed in their carriages *d d*.

Fig. 641 is a view of the cast iron wheel with the malleable iron tyre This wheel is made with curved spokes, as shewn at *a a a a a a a a a*, in the figure, and with a slit or aperture in the rim, shewn at *b*, into which a key is inserted. The reason of this is, that on the application of the hot tyre the cast metal expands unequally, and the rim is liable to be cracked, and the arms drawn off, unless the first is previously slit or opened, and the latter curved, which allows them to accommodate themselves to the increased diameter of the wheel; by this formation of the wheel the tyre might be forced on when cold, and keyed up afterwards.

Fig. 642 is a cross section of fig. 641, through the centre. *a a* show the tyre, *b b b b* show the metal rim. This cast metal rim is dovetailed; so that when the tyre, which is dovetailed to suit it, is put on hot, it contracts and applies itself to the rim with a degree of adhesion which prevents its coming off from the motion of the wheel on the rail-way. This wheel is of the form to suit an edge railway, and to make it answer for a plate rai' 't only requires the rim to be round or flat.

Fig. 643 is an end view of fig. 641, without the malleable iron tyre.

Fig. 644 represents a view of a rolley or tram-wheel, calculated to move upon a plate railway. *a a a a* show the malleable iron arms, fastened to the projections *b b b b*, on the inside of the rim *c c c*, by the bolts *d d d d*.

Fig. 645 is a cross section of fig. 644, through the centre of the wheel. *a a* show the arms, *c c* the rim, *d d* the bolts.

Fig. 646 represents a view of a rolley or tram-whee', with a plate of malleable iron *a a a a*, to form the junction between the nave *b b* and the cast metal rim *c c c c*.

Fig. 647 is a cross section of fig. 646. *a a* show the plate upon which the nave *b b* is cast. *c c* show the cast iron rim which is cast upon the plate, the edges of which plate are previously covered with a thin coating of loam and charcoal dust, or other fit substance, to prevent the too intimate adhesion between the iron plate and metal rim, so that if the rim should break, it can easily be taken off and replaced by casting another on the plate.

Fig. 648 represents the plate railway on their plan. At the end of each plate are projections *a a a a*, to fit into the dovetail carriage *b b*, and at each end of each plate are projections or tenons *c c c c*, which fall into the mortise hole (*d*, in Figs. 649 and 650) in the carriage *b b*, and secure the rail from an end motion; and when the pin or key *e* is driven into its place, it secures the plates from rising, thus they are fixed immovable in their carriages.

Fig. 649 is a front view of fig. 648.

Fig. 650 is a plan of the carriage, in which *a a* show the nail holes through which the nails are driven, to secure it to the sleeper. When the rails are laid in this carriage, and secured by the pin or key, they keep these nails from starting up by resting upon them.

Fig. 651 is a cross section of the carriage, and the end of one of the plate rails.

Fig. 629* shews a rail of the common way, inclining out of the horizon tal position, as they very often do from the yielding of the props or pedestals, and of course a shock is sustained by the waggons in passing the joining to the next rail

The ease with which cast-iron can be made into any required shape has till very recently given to rails of that material a decided superiority over those of malleable-iron. But the brittleness of the former renders such rails very liable to be broken, unless, indeed, they be of such substance as will resist the effects of the blows or shocks to which they are exposed, and which will require them to be of considerably greater weight than otherwise would be necessary. To obviate this, numerous experiments have been made with a view to substitute malleable-iron for cast-iron rails.

Rails of malleable-iron appear to have been first used at Lord Carlisle's works, at Tindal Fell, in Cumberland, about the year 1808; and though found there, and also at two or three other places at which they were tried, to be a saving in the first cost, and much less liable to accident, they have not till very lately been much used. In fact, it was not till some time after Mr. Birkinshaw, of the Bedlington Iron Works, had obtained a patent for malleable-iron rails of a new and improved construction, that rails of this material came into competition with the cast-iron rails.

The form of the malleable-iron rails previously to this was that of a parallelopipedon; which was liable to two objections, either that the narrowness of the surfaces, when compared to the breadth of the rim of the carriage wheel, was so considerable as to expose both the wheel and the rail to great injury from wear; or, if the breadth of the rail was increased to remove this objection, the weight of the rail would make the cost amount to almost a prohibition of its use.

Mr. Birkinshaw obtained his patent in October 1820; and the improvement consisted in making the rails in the form of prisms, though their sides need not of necessity be flat. The upper surface, on which the wheel of the carriage is to run, is slightly convex, in order to reduce the friction; and the under part, which rests on the supporting blocks, chains, rests, standards, or pedestals, is mounted upon the sleeper. The wedge form is proposed, because the strength of the rail is always in proportion to the square of its breadth and depth. Hence this form possesses all the strength of a cube equal to its square, with only half the quantity of metal, and consequently half the cost of the former rail. Sufficient strength, however, may be still retained, and the weight of metal further reduced, by forming the bars with

concave sides, which is the form of rail the patentee decidedly prefers, although the prism or wedge form, in all its varieties, is the principle upon which his patent-right is founded.

The mode of making these wedge-formed rails of malleable-iron is, by passing bars of iron, when heated, through rollers, having grooves or indentations cut upon their peripheries, agreeably to the intended shape of the bar to be produced. But, though the patentee recommends, and adopts this mode as the most eligible means of producing these rails, he claims the exclusive right of manufacturing and rendering the wedge-formed bars or rails of any length, for the purpose of forming or constructing rail-roads.

The advántages derived from this method of constructing railways may be as follows :—

1st. The original cost of a malleable-iron railway is less than a cast-iron railway of equal strength.

2dly. As the rails can be made in the lengths of 9,12,15, or 18 feet each, and even longer when required, the number of joints is hereby reduced; and thus is removed, in a great measure, the liability to which the short rails now in use are exposed, of receiving blows and shocks from the carriages which move over them.

3dly. In order to remedy the evil arising from the rails being imperfectly joined, the plan of welding the ends together has been adopted; by this means making one continued rail the whole length of the road without any joint whatever.

4thly. It hence follows, that on iron railways, the loss of coals, occasioned by the jolting of the waggons at the joints of the rails, and the injury done to the wheels, the carriages, and engines from the same cause, are, if not entirely prevented, at least considerably diminished.

In September, 1821, Mr. Losh took out another patent for further improvements in the construction of railways. These improvements consist, first, in fixing bars of malleable iron on the upper surface of a line of cast or malleable iron rails, of whatever form such rails may be, in the longitudinal direction of the rails when laid, so as to form an uninterrupted line the whole length of the bar, which may be as long as it shall be found convenient, and of the same breadth, or a little broader or narrower than the upper surface of the rails to which it is fixed. Secondly, in fixing, in some cases, a band or strap of malleable iron to the under surface of cast-iron rails, in order that such strap or band may, by its power of tension, give support to

the cohesion of the parts of cast iron rails, and admit of its being made lighter, of less expense, and less liable to breakage. Thirdly, in forming a rail, by fixing two bars of malleable iron on their sides or edges, and fixing them in that position by bolts and studs, or any other convenient method; and in placing and fixing on their upper edges a flat bar of malleable iron, or one which is slightly curved or rounded at the edges to diminish friction, so that the bar or plate, placed and fixed on the upper edges of the two malleable iron bars, shall form the surface upon which the wheels of the carriage are to revolve.

Mr. Losh states, in the specification of his patent, that rail-roads are now become so general, that for the information of mechanical men, or those who have the direction of constructing and laying them, drawings would be quite superfluous; he therefore proceeds to state the methods which he has found the most convenient, for forming the junction of the plate or flat bar, which he applies upon the surface of the body of the rail; and also the mode by which he attaches the band or strap to the lower edge of the cast iron rail.

He recommends the dimensions of the bars meant to form the upper surface of a railway, calculated to carry locomotive engines of seven or eight tons, and waggons of three or four tons weight each, to be fifteen or sixteen feet long, two and a quarter inches broad, and half to five-eighths of an inch thick. At every eighteen inches or two feet of the length of this surface-plate, a tenon is firmly welded or riveted; or otherwise attached to the under side, taking care in this operation to leave the upper surface of the plate even as before. These tenons have holes through them in the transverse direction of the bars, to take a pin or rivet of from about a quarter to half an inch in diameter; and at each extremity of the plate, a tenon is fixed on by welding, having previously cut off a piece of about two inches long, and of half the breadth of the bar, from the opposite ends of the bar or plate, and at the opposite angles, so that when two bars, so prepared, are brought to join at the ends, the joint is what is denominated a half-lap, or scarfed joint.

If it be required to place malleable iron plates or bars on cast iron rails, nothing more is necessary than to make the rails with mortise holes, to receive the tenons with transverse holes, to correspond with those in the tenons fixed on the plates; and, after placing the rails in their chairs or carriages, to apply the plate to the surface of the rails, and

to drop the tenons into the mortise holes, and to secure them there by a pin driven tightly into and through the transverse holes of the tenons and mortise holes. The mortise holes are made in the rails by placing a core in the mould previously to running in the metal, and lest this core should weaken the rail, it is advisable to add as much metal on the outside of the rail, in the form of a boss, where the hole is, as will make up the deficiency. A chair is then placed on a pedestal at every three or four feet distance, less or more, according to the length of the cast iron rails ; and each of these must be supported at its ends : these rails are generally made with half-lap joints, and to rest on a curb bearance. Care is taken that, where the ends of the surface-plates meet to form a joint, they shall be sustained by a chair; and the reason for making the joints half-lapped, or scarfed, with tenons welded to these half laps is, that one pin or bolt will secure both the adjoining ends of the surface-plates, and of the bars of cast iron, more perfectly in the chair, than any other known contrivance, when the bearance is the apex of a curve. Surface-plates thus prepared with tenons, as described above, may be attached and fixed to the upper surface of a series of malleable iron rails placed in chairs, which rails consist of flat bars (generally three or four feet long, more or less, but sometimes also as long as the surface plate), fixed on their thin edges, so as to present the greatest resistance to a weight bearing upon them. For this purpose, pins or rivets may be driven through the transverse holes in the tenons on the surface-plate, and the corresponding transverse holes made in the supporting bars ; and thus may be formed a cheap and very serviceable railway. In this case, the supporting bars should not be less than two and a half inches deep, by half an inch thick, if meant to carry locomotive engines. For smaller carriages, the bars may be of less dimensions, in proportion to the decreased weight of the carriages.

In forming the rail, consisting of a plate of malleable iron, supported by two flat bars of the same material, Mr. Losh prepares the surface-plate as above with tenons, and having fixed the two bars intended to support it on their edges, parallel to each other, in a series of chairs, and secured them in that position by bolts passing through them, and by intervening studs, to keep them at a proper distance, which is such, that the sides or edges of the surface-plate, which may be a little curved or rounded, to diminish the friction from the wheels passing over it, shall project about

a quarter of an inch beyond them. By these intervening studs, the surface-plate is laid upon them, and the tenons are dropped in between them, and fixed by pins or bolts passing in a transverse direction through holes in the bars, which are made to correspond with holes in the tenons, and thus securing them as if they were in mortise-holes. The strap or band of malleable iron is fixed by Mr. Losh to the under edge of the cast-iron rail, by perforating both ends of the strap, near the extremities, with a long hole, calculated to pass over studs of malleable iron which are fixed at each end of the rail, by being run at the time of casting the rail or otherwise. The studs should be about one and a half inches broad, by three-eighths of an inch thick, and placed so, that when the strap has been put over them in a heated state, it cannot, in contracting, slip its hold; but will, on the contrary, fix itself the closer. These straps are made of malleable iron bars, about one and a half inches broad, three-eighths to half an inch thick, and of such length as to draw strongly against the studs and bottom of the rail, when in its position. The under edge of the cast iron rail to which this strap is applied being curved, it will, when the strap is fixed upon the studs, by an extension of its length by heat, apply itself firmly to, and support every part of the lower edge of the rail, in contracting, by parting with its heat; and till the power of tension of this strap is overcome, and it extends in length, or the studs break, the rail cannot give way.

Many other methods, perhaps equally secure, may be made use of to place and fix surface-plates on the surface of rails; but Mr. Losh prefers the plan pointed out, by tenons and mortise-holes, and by rivets passed through holes in such tenons, and through corresponding holes in the supporting bars; because, when worn or damaged, these plates can easily be taken off and replaced, without injury to that part of the rail which supports them.

The principal patents obtained before the above described, are those by Blenkinsop, Brunton, and Chapman; specifications and drawings of which may be seen in the Repertory of Arts.

Mr. Blenkinsop's patent was obtained the 10th of April, 1811, and is for a method of fixing into the ground a toothed rack, or longitudinal piece of cast iron, or other fit material, having teeth, or protuberances, into which a toothed or cogged wheel, connected with a locomotive carriage, plays.

Mr. Brunton's patent was taken out the 22nd of May, 1813, and is for a method of propelling machines along a railway by means of two or more bars or legs, which, by receiving a reciprocating motion from a steam engine, act against the ground like a man's legs, when in the act of walking. These bars or legs are constructed of metal or wood, and of such length that, during the act of propulsion, the angle formed by the said bars or legs and the surface of the road may be such, as to afford sufficient resistance from the materials propelled against to overcome the friction of the body to be moved. This angle admits of considerable latitude; but will be found to answer best when between 50 and 70 degrees.

The reader has now been informed of the principal patents that have been taken out for improvements in rail-roads. The rails most in use are those of cast-iron by Losh and Stephenson, and of malleable-iron by Birkinshaw.

Previously to constructing a railway, it is necessary to ascertain, as accurately as the nature of the thing will admit, the quantity of lading expected to traverse each way upon its line. For if the weight of the carriage of merchandize, &c. be more in the one direction than in the other, as will frequently be the case in forming a line of railway from a manufacturing or mining district to a town, the railway must have a gentle inclination or descent; but if the lading is expected to be nearly equal in both directions, with a preponderance at certain periods only, the railing must, in such case, be set out in levels, or in lines nearly level, and the ascents and descents made by planes inclined accordingly.

That the reader may see the necessity of paying due attention to this point, we shall show the advantages that will result from constructing railways with a gentle gradual descent, when the carriage of the articles of trade are considerably more in one direction than the other.

Dr. Armstrong, in his Recreations in Agriculture, observes, that a horse, travelling at the usual rate that waggons move, would, with ease, under favourable circumstances, draw 20 tons: but Mr. Fulton says, that five tons to a horse is the average work on railways, descending at the rate of three miles per hour; or one ton upwards with the same speed. Mr. Telford, an experienced engineer, observes, that on a railway well constructed, and laid with a declivity of 50 feet in a mile, one horse will readily take down waggons containing 12 to 15 tons; and bring back the same waggons with four tons in them. Mr. Joseph Wilkes, in

1799 stated, that a horse of the value of 20*l*. drew down the declivity of an iron road, $\frac{4}{18}$ths of an inch in a yard, 21 carriages or waggons, laden with coals and timber, weighing 35 tons, overcoming the *vis inertiæ* repeatedly with ease. The same horse, up this declivity, drew five tons with ease. On a different railway, one horse, value 30*l*. drew 21 waggons of five cwt. each, which, with their loading of coals, amounted to 43 tons eight cwt., down the declivity of 1-3d of an inch in a yard; and up the same place he afterwards drew seven tons; the cwt. in all these experiments by Mr. W. being 120lbs.

Though in the preceding statements there is an apparent variance, the authors are not the less entitled to credit; because the variations may have arisen from difference in the physical strength of the animals, or in the method of constructing the railways. To make the case, however, as clear as possible, we shall here present our readers with some observations and calculations deduced from known data, which have lately appeared in a very able pamphlet, entitled "A Report on Rail-Roads and Locomotive Engines," by Mr. Charles Sylvester, civil engineer.

Mr. Sylvester, having made some judicious observations on the principles of railways, and the nature of the friction to be overcome, states, that, "agreeably to the principles laid down in the commencement, when a force is applied equal to the friction, the smallest force above that would, if continued, generate any required velocity. But it will be desirable to have such a force at command, as will generate the necessary velocity in a short time, and when that has been accomplished, to reduce this force, but still to leave it fully equal to the friction. If any part of the route has an inclination, there ought to be an extra force at command, above what would be required for a dead level. The plane on which this experiment was made, inclined, in the direction of the load, about $\frac{1}{9}$ of an inch to a yard. This is as great, or perhaps a greater, inclination than any rail-road ought to have, where loaded carriages go up and down. The moving force ought, therefore, to be always greater than the friction added to the force which is required to overcome the inclination of the plane. The latter force assists the body to go down, and equally resists it in moving upwards.

"On this account" says he, "I have used, or supposed, a moving force, which will give the velocity of 5 miles an hour, or $7\frac{1}{3}$ feet per second, in the space of one minute. This will be performed down the above plane by the engine making

45 strokes per minute, (the circumference of the wheel being nine feet), with a pressure of 9·7lbs. upon an inch, of each of the two cylinders, the area of each being 63·6 square inches. The weight of the engine and 16 waggons is equal to 154,560lbs, or nearly 70 tons. The velocity of five miles an hour being acquired after one minute, the only force to keep the whole in motion, at the same rate, will be the difference between the gravity of the weight down the plane and the friction. The friction is 900lbs; the gravitating force of the weights down the plane 540lbs; therefore $900 - 540 = 360$lbs.

"If the same weight, at that speed, had to move on a dead level, and acquired the same velocity in one minute as before, the moving force would require to be 1781lbs. which would require a pressure of 13·7lbs. upon one inch. But after the speed is obtained, it will require only 7lbs. to keep it moving at the same rate. If the same load were required to move up the plane, it would require a moving force of 2328lbs. or a pressure upon every square inch of 18·3lbs. And this velocity would be kept up by a constant pressure of 1447lbs. which will be 11·3lbs. upon every inch of the piston.

"In starting the engine, in the first instance, and giving the required velocity, it is probable the effects will agree very nearly with these calculations; namely, 154,560lbs. moved at the rate of five miles an hour, with a pressure of 9·7lbs. upon every inch of the piston. Whether the pressure were reduced to the difference between the friction and the force upon the plane, which is calculated at 2·8lbs. it is difficult to say, as there was no steam-gauge to indicate the pressure when the engine was going."

In table 1, at a more advanced part of the work, Mr. Sylvester states, that, when the engine is required to travel at the rate of nine miles per hour, the force necessary to overcome the weight, 154,560lbs. will be for the first minute, when the engine is travelling on a level 2890·81lbs; when moving down the plane 2461·61lbs; and when moving up the plane 3320·01lbs. But that, when the velocity is attained, a force that will balance the friction is sufficient to keep up the required velocity. This force is, for travelling on a level, 900lbs; for moving down the plane, 471lbs; and for moving up the plane 1329lbs.

By this, therefore, it is evident that, when the lading is expected to be considerably more in one direction of the line of rail-road than it is in the other, the advantage which

will arise from making the road with a gentle slope, is very great. This kind of railing is also preferable when the lading is only equal at certain periods. For then the expense of extra horses, to draw the additional weights up the plane during these periods, will fall infinitely short of the expense saved by making the plane with a gentle inclination.

The necessary preliminaries being settled, the engineer will obtain much greater facility, as also a diminution of expense, by beginning to lay down the rails on any part of the intended line of road where stone, gravel, and other materials that are wanted, are to be most conveniently had ; as, by that means, he will evade the slow and expensive mode of common cartage.

The immense sums that have been invested in the hands of certain companies, for the purpose of establishing general lines of rail-road throughout the country, have excited much interest and elicited many able papers from practical men, in several of the publications of the day. Amongst these, perhaps those inserted in the Scotsman, an Edinburgh newspaper, and in the Manchester Guardian, are the most deserving of our notice.

The Scotsman first commences with some theoretical statements, and then continues :

Having developed the theory of the motion of carriages on horizontal railways, we shall have little more to do with mathematical discussions, and shall now turn our attention to points of a practical nature, better adapted to the taste of ordinary readers. But first, we shall bring under the eye again, the effect of a given quantity of power on a railway, and on a canal, in a calm atmosphere—for it is only in a calm atmosphere that the results can be properly compared.

We have found that a *boat* weighing with its load 15 *tons, and a waggon of the same weight*, the one on a canal, and the other on a rail-way, would be impelled at the following rates, by the following quantities of power—which we have stated both in pounds and in horse power—reckoning one horse power equal to 180 pounds.

	Boat on a Canal.		Waggon on a Rail-way.	
Miles per hour.	power in pounds.	Horse power.	power in in pounds.	Horse power.
2 - -	33	1-5th	- - 100	$\frac{1}{2}$
4 - -	133	2-3ds.	- - 102	$\frac{1}{2}$
6 -	300	$1\frac{3}{4}$	- - 105	$\frac{1}{2}$
8 - -	533	3	- - 109	$\frac{1}{2}$
12 -	1200	7	- - 120	2-3ds
16 - -	2133	12	- - 137	$\frac{3}{4}$
20 -	3325	18	- - 158	1

We have not taken into account the time lost in overcoming the *inertia* of the waggon where a small power is applied, because, in point of fact, the casual resistance of the wind would render it necessary to provide double or triple the power above stated. But if necessary, the time lost by the slow motion at first might be saved. Suppose there are a certain number of places where the steam-coach or waggon was to stop, to take in or put out passengers or goods; and farther, that the waggon, by travelling a few miles, has acquired an uniform velocity of 20 miles an hour. Then, if it is made to ascend an inclined plane of 10 feet perpendicular height, this velocity will be extinguished, and the vehicle will stop at the head of the plane. When it is to proceed again on its journey its descent along an inclined plane of the same height on the other side, will enable it to recommence its career in a few seconds with the full velocity of 20 miles an hour. By raised platforms of this kind, at the two extremities of the journey, and at the intermediate stages, the velocity thus generated, might be treasured up for permanent use. The platforms should be of different heights, corresponding to the various velocities of the vehicles plying on the railway. But, in point of fact, the terminal velocity is attained so soon from a state of rest, that this contrivance would probably be found unnecessary.

Where locks or *lifts* occur, the stationary steam-engine should drag up the vehicle (supposing it to be along an inclined plane), not simply from the one level to the other, but to a platform some feet above the higher level, that the vehicle, by its descent, might recover the lost velocity. It is plain, however, that when the difference of level did not exceed eight or ten feet, the momentum of the vehicle would carry it up without any assistance from a stationary engine, and with merely a small temporary loss of velocity.

Some persons imagine erroneously that teethed wheels and rackwork would be necessary where the railway was not perfectly level. But the friction of iron on iron being 25 per cent. of the weight, if the whole load was upon the wheels to which the moving power was applied, and if the quantity of power was sufficient, the waggon would ascend without slipping though the plane rose one foot in four—while even cart roads scarcely ever rise more than one foot in 18 or 20. If four-fifths of the load, however, were placed on separate cars, and only one-tenth of the whole pressure, for instance, was upon the axle to which the moving force

2 U 2

was applied, the power of ascent by friction would only be one-tenth of one foot in four, or one foot in forty.

The steam engine, as we commonly see it, is so bulky, and with the addition of its fuel and supply of water, so ponderous, as to create an impression on a first view, that its whole power would scarcely, under the most favourable circumstances, transport its own weight. The steam-boat, however, which cuts its way through the ocean, in defiance of tide and tempest, shews that this is a mistake. For all velocities above four miles an hour, the locomotive engine will be found superior to the steam-boat; that is to say, it will afford a greater amount of *free* power, above what is required to move its own weight.

We have seen various statements respecting the locomotive engine, few of them so detailed as could be desired— from which we subjoin the following particulars:

Trevithick and Vivian's high pressure locomotive engine, with a cylinder of eight inches diameter, and a pressure of 65 pounds per square inch (apparently about eight horse power), drew carriages containing ten and a half tons of iron, at five and a half miles per hour, for a distance of nine miles. (Stuart's History of Steam Engine, p. 164.) Whether on a road or railway is not mentioned.

We find it stated in a Liverpool paper, as the result of inquiries made respecting the locomotive engines, that one of these, of ten horse power, conveys fifty tons of goods at the rate of six miles an hour on a level railway. But was the road an edge or tram road?

Mr. Blenkinsop states, in replies to queries put by Sir John Sinclair, that his patent locomotive engine, with two eight-inch cylinders, weighs five tons, consumes 2-3d cwt. of coal, and fifty gallons of water per hour, draws 27 waggons weighing 94 tons on a dead level, at three and a half miles per hour, or 15 tons up an ascent of two inches in the yard; when 'lightly loaded' travels 10 miles an hour, does the work of 16 horses in 12 hours, and costs 400l. Another person says, that the weight of this engine with its water and coals is six tons, and that it draws 40 or 50 tons (waggons included) at four miles an hour on a level railway. (Repertory of Arts, 1818, p. 19-21 This seems to have been a high pressure engine of about eight or ten horse power. But we are not informed what sort of railway it worked on, how long its journies were, or what is meant by 'lightly loaded.'

We shall take for granted then that an eight-horse

power high pressure engine, with its charge of water and coal, and with the car which bears it, weighs six tons, and that it requires an additional supply of 100 weight of coal, and 400 weight of water for each hour it works. This is very consistent with other ascertained facts. We find, for instance, in the parliamentary report on steam navigation, that the low pressure engines used in vessels, which are made twice as strong as stationary engines, weigh about one ton and one-fifth for each horse power, including their charge of water and coal. Now the high-pressure engines want the condensing apparatus which must diminish the weight probably by one-fourth part. The estimate for coal we have increased one-half, because we think it rather below the truth. It is only about nine pounds per hour for each horse power, while Mr. Watt allows twelve pounds for his low pressure engines.

It follows, therefore, that an eight-horse power locomotive engine, with coal and water for eight hours, would weigh eight tons. Hence, bulky and ponderous as the steam-engine appears, we find that a locomotive engine, weighing eight tons, moves 50 tons beside itself, (taking the more mŏderate estimate,) that is, it consumes only one-seventh part of the power it creates, when travelling at four miles an hour; or *the free power applicable to other purposes, is seven-eighths of the whole.* This is the result of an early experiment, made probably upon a rail-road not of the best kind, and with vehicles much less perfect than they may yet be rendered. Though it falls much under the effect calculated theoretically, it does not strike us as being inconsistent with the truth of the principles on which the calculation was founded.

The high pressure engine, on account of its smaller weight and bulk, is evidently best adapted for railways; and it can be used with perfect safety, because it may be easily placed in a car by itself, a few feet before the vehicle in which the passengers are. The vehicle itself, by its regular and steady motion on the railway, would answer the purpose of a *fly-wheel* in the most perfect manner. The engine might run upon six wheels, which should be locked together by teeth pinions, that the tendency to slip might be resisted by the friction of the whole mass of eight tons.

The best form of a steam coach for the conveyance of passengers would probably be the following:—A gallery seven feet high, eight wide, and 100 feet in length, formed into 10 separate galleries 10 feet long each, connected with

each other by joints working horizontally, to allow the train to bend where the road turned. A narrow covered footway, suspended on the outside over the wheels on one side, would serve as a common means of communication for the whole. On the other side might be outside seats, to be used in fine weather. The top, surrounded with a rail, might also be a sitting place of promenade, like the deck of a track boat. Two of the 10 rooms might be set apart for cooking, stores, and various accommodations; the other eight would lodge 100 passengers, whose weight, with that of their luggage, might be 12 tons. The coach itself might be 12 tons more; and that of the locomotive machine, eight tons, added to these, would make the whole 32 tons. Each of the short galleries might have four wheels; but to lessen the friction, the two first wheels only should be grooved, the two last cylindrical, and three or four times as broad as the thickness of the rail. The conveyance of goods would be effected by a train of small waggons loosely attached to each other.

It will be observed from the table we have given above, that it would require seven horse power to impel a steam-boat weighing 15 tons at 12 miles an hour. This gives a load of two tons so moved; however, the engine, if a low pressure one, with water and eight hours' coals, would weigh nearly 10 tons, and the vessel would weigh at least five; so that the whole power of the engine would be expended in impelling itself and the ship containing it, at the supposed rate, and no *free* power would remain for freight. Facts show that the resistance is actually rather greater in water than theory in this case represents it. We have calculated from data furnished by the Parliamentary Report on steam navigation, that the entire burden on the engine in vessels going only eight or nine miles an hour in calm weather, rarely exceeds three tons for each horse power, while, according to the table, it should be five tons. Indeed, in our common steam-vessels for passengers, going eight or nine miles an hour, the ship and engine may be considered as constituting the whole burden. For 50 passengers, weighing perhaps with their luggage six or eight tons, placed on board a ship weighing, with her engine of 60 or 70 horse power, a hundred and fifty or hundred and eighty tons, form but an addition of one-twentieth or one thirtieth to the mass—a quantity of no importance in a practical point of view. If we convert the steam-engine power into real horse power, and figure to ourselves 100 horses employed to

draw 50 persons, we see what an enormous waste of power there is in the mode of conveyance. We may remark further, that the tenor of the evidence given before the Parliamentary Committee renders it extremely doubtful, whether any vessel could be constructed, that would bear an engine capable of impelling her at the rate of two miles an hour, without the help of wind or tide.

When the steam coach is brought fully into use, practice will teach us many things respecting it, of which theory leaves us ignorant. With the facilities of rapid motion which it will afford, however, we think we are not too sanguine, in expecting to see the present extreme rate of travelling doubled."

This practicability of conveying individuals or merchandize at the speed required in the present improved state of our internal intercourse with the different parts of the kingdom, has created much doubt and discussion with many able and practical mechanics. The question seems to resolve itself thus, Do the friction incurred by any moving body, laying aside the resistance of the atmosphere, increase in proportion to its velocity?

Without going into any diffuse or theoretical argument on this point, we shall merely cite that by the results of actual experiments instituted by Vince and Coulomb, it appears *that friction does not increase in proportion to the velocity.* By experiments made also by Stephenson and Wood, it appears that the force required to keep a given weight in motion does not vary with the velocity: thus, a force of 14lbs. was found to overcome friction, and keep in motion an empty coal waggon, weighing 23·25 cwt. on a rail-road; and that on doubling the velocity, no more force was required. Further also it appears, that on increasing the weight, or load, the power required to overcome the friction, and keep the waggon in motion, did not increase in similar proportion, but up to 76·25 cwt. was about one-fourteenth less.

Notwithstanding the simple and satisfactory manner by which the experiments that led to these results were conducted, the fact has been still much doubted. We cannot therefore do better than to extract from the Manchester Guardian the following article, which contains an account of experiments, with most conclusive results, made by that able mechanic, Mr. Roberts of Manchester:—

"The object of the papers on rail-roads which appeared in the Scotsman, was, in a great measure, to shew the prac-

ticability of transporting commodities upon rail-roads at a very considerable speed; and (with some fallacies, which we shall endeavour to point out) they contain a great deal of valuable information, on the relative merits of highways, canals, and rail-roads. The principal point, however, and the one to which we shall confine our observations, is an enunciation of the laws which regulate the friction of rolling and sliding bodies, as deduced from the experiments of Vince and Coulomb. With a view to the illustration of this part of the subject, some very important and conclusive experiments have recently been made in this town, to which we shall by and by have occasion to refer at some length; but before doing so, we must make a few observations on the rule laid down by the Scotsman, and the misconceptions which appear to have prevailed respecting it, both in that journal and in other quarters.

After comparing the resistance experienced by a boat moving through the water, with the friction which retards the progress of a waggon on a rail-road, and stating that they are governed by different laws, the Scotsman notices the conclusions established by the experiments of Vince and Coulomb; the most important of which is, that the *friction of rolling and sliding bodies is the same for all velocities.* The writer then observes:—

'It is with this last law only that we have to do at present; and it is remarkable that the extraordinary results to which it leads, have been, as far as we know, entirely overlooked by writers on roads and railways. These results, indeed, have an appearance so paradoxical, that they will shock the faith of practical men, though the principle from which they flow is admitted without question by all scientific mechanicians.

'First. It flows from this law, that (abstracting the resistance of the air,) if a car were set in motion on a level railway, with a constant force greater in any degree than is required to overcome its friction, the car would proceed with a motion continually accelerated, like a falling body acted upon by the force of gravitation; and however small the original velocity might be, it would in time increase beyond any assignable limit. It is only the resistance of the air (increasing as the space of the velocity) that prevents this indefinite acceleration, and ultimately renders the motion uniform.

'Secondly. Setting aside again, the resistance of the air (the effects of which we shall estimate by and by,) the very

same amount of constant force which impels a car on a railway at two miles an hour, would impel it at ten or twenty miles an hour, if an extra force were employed at first to overcome the *inertia* of the car, and generate the required velocity. Startling as this proposition may appear, it is an indisputable and necessary consequence of the laws of friction.

'Now it would at all times be easy, as we shall afterwards show, to convert this accelerated motion into a uniform of any determinate velocity; and from the nature of the resistance, a high velocity would cost almost as little, and be as readily obtained as a low one. For all velocities, therefore, above four or five miles an hour, rail-ways will afford facilities for communication prodigiously superior to canals, or arms of the sea.'

Now we are perfectly satisfied, both by the experiments of Vince and Coulomb, and those more recent and conclusive experiments, to which we have already alluded, that the rule laid down here is correct; but the writer ought to have guarded against the misconception to which his last paragraph is liable. When he says that a high velocity would cost almost as little as a low one, he should have said that it would cost as little per mile, or as little over any given space: for it cannot be his meaning, that a carriage can be kept moving for an honr, or for any given time, at a high velocity, with as little expenditure of power, as at a low velocity. Yet this he has been generally understood to mean, and a great deal has been written and said with a view to prove that he was mistaken; when in fact he was only misunderstood. In a subsequent article, however, the author appears, in some degree, to have fallen into the same error into which he has led other persons. He says:

'Every body knows that the rate of stage coach traveling in this country has increased within the last twenty-five years, from six or seven miles an hour to eight or nine, and this, too, before roads were M'Adamized, and with much less injury to the horses than was anticipated. Supposing that a coach-horse could run fourteen miles unloaded, with the same muscular exertion which carries forward the stage-coach at eight or nine miles, then professor Leslie's formula becomes 3-4ths (14 v)2. Each horse would, of course, draw with a force of 48lbs. at six miles, and of 27lbs. at eight miles an hour. But if the friction increased in the ratio of the velocity, the load upon each horse would increase from 48lbs. to 60lbs., when the speed increased

from six to eight miles an hour: and as the horse exerting the same strength, would only pull with a force of 27lbs., he would thus have more than double work to do, which is plainly impossible. But admit that the friction is equal in equal times; then, since the time is diminished 1-4th by increasing the speed from six to eight miles an hour, the horses have actually 4-5ths less to do; the load upon each is reduced from 48lbs. to 36, and the horse would have to increase its exertion only 1-3rd, that is, from 27lbs. to 36. The facts, we believe, will be found strictly consistent with this hypothesis, and decidedly at variance with the other. However strange it may sound, then, to common observers, it is practically true, that a smaller absolute amount of force will drag a coach over the same space in three hours than in four, and in one than in two.'

This paragraph seems to us to contain a very obvious fallacy. If the speed be increased from six miles an hour to eight, the horses have by no means 1-4th less work to do, supposing the friction a constant quantity, and the traction consequently the same. It is true that they exert this power for a shorter time, but it is over the same distance. Supposing the power of traction necessary to overcome the friction is 1000lbs., then that power must be extended over every yard of the distance, whether the carriage moves at six or eight miles an hour: and it is by the distance, not the time, that the power must be measured. That this must be the case, will be obvious if the experiment be put in another shape. Suppose a perfectly horizontal railway, a mile long, with a perpendicular descent of a mile at one end of it, as represented in fig. 652.

Suppose a waggon placed on this railway at A, attached to a rope passing over a pulley at B, and loaded at that point with a weight exactly sufficient to overcome the friction, then, if the resistance of the air is nothing, and the rope be without weight, it follows, from the rule laid down, that if the waggon is set in motion at any given speed, it will continue to move at that rate, until it reaches the point B and the weight falls to C. But whether the waggon passes over the railway in an hour or in three minutes, it is obvious that the same weight will descend through the same space, and that consequently, the same amount of power will be expended. It is, perhaps, necessary to observe here, that if the weight is only just sufficient to overcome the friction, there will (as is proved by

the experiments of Mr. Vince) be no acceleration of motion on the principle of falling bodies.

However, though a carriage cannot, as we think we have shewn, be moved ten miles in one hour, with a similar expenditure of power than in two, it is very interesting to know that it can be moved with the same expenditure, (excepting the resistance of the air.) In many cases dispatch is of so much consequence, that the elucidation and application of this rule will probably lead to very important results. Many persons, however, are very sceptical on this subject, and contend that the experiments of Vince and Coulomb do not authorise any such conclusions as have been drawn from them. It has been asked, if the same constant force will move a carriage as well at a high as at a low velocity, why we do not see something like this in practice; why a carriage moved by a steam-engine instead of acquiring, as it proceeds, a high degree of velocity, moves on at one uniform rate after it has overcome the *vis inertiæ* at the commencement of its journey? We think the reason is very obvious. A locomotive steam-engine does not exert the same constant force on the peripheries of the wheels of the carriage, when it moves at different velocities. For instance, suppose the piston of an engine to move 220 feet in a minute, and to impel the peripheries of the travelling wheels at a velocity of two miles, and with a force just sufficient to overcome the friction, how can the speed be augmented without increasing the power of the engine? If the diameter of the wheels be increased with the view of increasing the speed, the force with which they are impelled will be diminished in the same proportion; and the engine will stop, unless the pressure is increased. To increase that, of course, will be to augment the power. As it is obvious, therefore, that a steam-engine cannot exert the same force at different velocities, some other means must be devised for putting to the test of experiment the rule laid down in the *Scotsman.*

We now come to the most important and interesting part of this article. As none of the experiments of Vince or Coulomb (so far as we have seen or heard them detailed) were made with bodies resembling railway waggons, either in form, or in the nature of their motion, the correctness of the conclusions deduced from them with respect to such carriages, was doubted by many persons of considerable scientific attainments. It became desirable, therefore, that other experiments should be tried, with carriages

upon railways, which, of course, would be much more satisfactory. This, however, it did not, at first sight, appear very easy to accomplish in a satisfactory manner: but Mr. Roberts, of this town, recently devised a mode of determining the point, which appears to us wholly unobjectionable, and which exhibits, in a high degree, the simplicity and facility of execution, by which that gentleman's inventions are so eminently distinguished. It was very difficult to devise means for measuring accurately the friction of a carriage moving over a railway; but it occurred to Mr. Roberts, that the difficulty would be obviated if the railway were made to move under the carriage. When this idea once presented itself, it was easy to reduce it to practice. Mr. Roberts therefore constructed an apparatus, of which fig. 654 will give a pretty correct notion.

A is a small waggon with four cast iron wheels, placed on the periphery of a cast iron drum B, three feet in diameter, and six inches broad, (which acts as the rail-road.) This drum is fastened on the same shaft as the pulley C, which is driven at different speeds by a strap from another pulley. The waggon is attached by a wire to one of Marriot's patent weighing machines D, for the purpose of measuring the friction, and the board G, prevents the current of air, occasioned by the motion of the drum, from acting upon the carriage. Now if the drum be driven with any given velocity, say four miles an hour, in the direction indicated by the mark E, and the waggon held in its place by the wire which attaches it to the index, it is perfectly obvious that the wheels will revolve on the drum in precisely the same manner as if the waggon moved forward on a horizontal road; and the friction will also be the same, except, perhaps, a small addition occasioned by the curvature of the drum, but which will not affect the *relative* frictions of different speeds. As the waggon is stationary, the resistance of the air will be entirely got rid of; and the index of the machine will indicate the precise amount of traction necessary to overcome the friction. Of course, in making the experiment, it will be necessary to keep the centre of the waggon *exactly over the axis of the drum;* for if it were permitted to go beyond the centre, a part of the weight would be added to the friction, if, on the contrary, it was brought nearer the index, a part of the weight would act against the friction, and diminish the apparent quantity. The tempering screw F, is therefore added to keep the waggon in its proper situation, in whatever way the spring of the weighing machine may be acted upon by the friction.

This simple apparatus having been constructed, a number of experiments were made, chiefly with a view to determine whether the friction were the same at different velocities. The waggon was loaded with fifty pounds, (including its own weight) and the drum was driven at different velocities, varying from two to twenty-four miles an hour on the periphery: but in every case, the friction, as indicated by the weighing machine, was precisely the same. No increase of speed affected the index at all, but on increasing the weight, it immediately shewed a corresponding increase of friction.

We consider these experiments as perfectly conclusive

of the fact, that the friction on a railway is the same for all velocities; and that a carriage may be propelled twenty miles in one hour, with the same amount of force which would be necessary to drive it twenty miles in ten hours, provided the resistance of the atmosphere was out of the question: and, if the carriage was properly constructed, that would not amount to much. In other words, goods may be conveyed from Manchester to Liverpool, on a rail-road, with very nearly the same expenditure of steam, whether they are carried two miles, or four miles, or twenty miles an hour. A steam engine, which will propel twenty tons at four miles an hour, will, with the same expense of coals, propel ten tons at eight miles an hour; so that, with the smaller load, it might make a journey to Liverpool and back, in the same time which would be occupied in going thither with the larger load Or, to put the matter in another shape: suppose a four-horse engine will convey forty tons to Liverpool in eight hours, an eight horse engine will convey the same weight thither in four hours. There will be the same expenditure of steam in both cases, but, in the latter, a saving of half the time; a saving which, we need not add, will frequently be of immense importance."

These practical results are very satisfactory, as the hope of propelling carriages at a suitable speed, for the more rapid dispatch of business, and conveyance of passengers, is thereby placed almost beyond a doubt.

We ought to notice here, the striking difference in the force requisite to give rapid motion on a rail-road to that on a canal or navigable river. These latter are governed by a totally different law, as the resistance, or head of water on the bows of the boat, increase as the squares of its velocity; consequently it will require four times the power to double the speed. But, on the other hand, it must be admitted, that in all speeds under three miles per hour, the cana has a decided advantage, as the force increases as the speed diminishes.

With respect to the horse, it is well known, that his power decreases as his speed increases; and that when he is travelling at his greatest speed, which, with a weight, seldom exceeds 13 miles per hour, he is able to exert little or no strength. We, therefore, take it for granted, that in the present improved state of our manufactures, artificial power of some description must be resorted to, and whatever experience may prove to be the most economical, the application of that power is the most important part of the

subject now under consideration. On this point, the data with which we are furnished is so very limited, as scarcely to render it possible to form any decisive opinion.

The engines which have been some time at work at Mr. Brandley's collieries, near Leeds, have a cogged wheel, playing in a rack, which is laid as one of the rails of the road; and those at Hetton colliery are much on the same principle. This plan is objectionable, because the whole weight of the engine, which, on the most improved construction, is not less than eight tons, is on the wheel, so that any obstacle on the rail, must of necessity shake the whole machinery. To obviate this, Mr. Gordon has contrived, and taken out a patent for a locomotive carriage with the engine on springs, which imparts the motion without any connexion with the wheels or axle-tree, and there are various other plans in progress for the same object. But let this be effected as it may, the great weight of the engine, which is by far the greatest objection, is not obviated. And, indeed, this appears to us only possible to be accomplished, by either diminishing the weight of the engine, as proposed by the application of Mr. Brown's pneumatic, or vacuum engine, or taking the engine entirely from the carriage, and employing stationary engines, at suitable distances, to tow or draw the carriages in regular succession. This last mode has been applied to practice in the vicinity of Newcastle, by Mr. Thompson; and the results may be seen in some very able observations annexed to the specification of his patent, and inserted in the Repertory of Arts, for March, 1822.

His method consists in dividing the line of Rail-road into any number of stages, at suitable distances apart. At the end of each stage an engine is erected for the purpose of drawing the carriages from the next stage, or engine, on either side, towards itself. This is effected by means of ropes, which, previously to commencing operation, are taken from each respective engine to the engine immediately before it by horses; but after the work has commenced, by being hooked at the end of the advancing or returning carriages.

In forming lines of rail-road upon this system, that is, where stationary engines are to be employed, it is not necessary that they incline in the direction of the loads, or be made perfectly level. For in engines of this description there is no occasion to pay that particular attention to the weight of the boiler and appurtenances, as is the case in engines

which have a locomotive principle. Indeed trifling inequalities of surface, which would be a material objection in the application of locomotive carriages, are, in the lines of road where stationary engines are employed, quite unheeded.

As many roads are traversed by night as well as by day, it becomes necessary that a signal should be given from one engine to the other as soon as the carriages have arrived and are hooked to its respective ropes, that the engine tender may not be at a loss when to throw his machinery into geer. For this purpose, Mr. Thompson recommends that the door of the fire-place of the boiler, or other strong light, be placed towards the engines on each side, so that, by opening it on that side which faces the engine, to whose ropes the carriages just arrived have been attached, the engineer may adopt such measures as will effect the desired purpose.

It is true, locomotive engines were not at that period so well understood as at present; but it appears to us that this point still remains in a very undecided state, and that from the even now limited experience in propelling carriages on railways, at a speed any thing like that of common carriages, it is very difficult to hazard an opinion. From the data, however, that can be collected, we certainly incline to stationary engines, as the most mechanical and economical application of the requisite power.

As to the degree of danger which travellers may be exposed to by locomotive engines, it cannot, under a proper management, exceed that of a steam-boat, or a factory, where power is operating. It is true, that as the weight of the engine is of great consideration, condensing engines (if steam be the force employed,) are quite inapplicable, and what are generally called high pressures must be introduced. But though all engines which do not condense their steam, and act only by the pressure, or elastic force, are called high pressure engines, there is no necessity whatever to go to dangerous heats, and with either wrought-iron or copper boilers and valves, placed out of the reach of the operative engineer, or engine tender, may certainly be worked at 45 or 53lbs. pressure, with as much safety as at 20lbs. in condensing engines. Indeed, on investigating the cause of steam explosions, they will be found to have rarely occurred but from the grossest ignorance and neglect.

Such of our readers who are desirous to have farther information on this interesting subject, we must refer to a very able report on rail-roads, by Mr. Charles Sylvester,

to the paper alluded to by Mr. Thompson, in the Repertory of Arts, for March, 1822, to a work which will shortly issue from the Press, by Mr. N. Wood of the Killingworth Colliery, of whose experiments, in conjunction with Mr. Sylvester, we have already had occasion to speak, and to Observations on a General Iron Railway, by Mr. Gray.

APPENDIX.

GEOMETRY.

Geometry is that branch of mathematics which treats of the description and properties of magnitudes in general.

Definitions or Explanation of Terms.

1. A *point* has neither length, breadth, nor thickness. From this definition it may easily be understood that a mathematical point cannot be seen nor felt; it can only be imagined. What is commonly called a point, as a small dot made with a pencil or pen, or the point of a needle, is not in reality a mathematical point; for however small such a dot may be, yet if it be examined with a magnifying glass, it will be found to be an irregular spot, of a very sensible length and breadth; and our not being able to measure its dimensions with the naked eye, arises only from its smallness. The same reasoning may be applied to every thing that is usually called a point; even the point of the finest needle appears like that of a poker when examined with the microscope.

2. A *line* is length, without breadth or thickness. What was said above of a point, is also applicable to the definition of a line. What is drawn upon paper with a pencil or pen, is not in fact a line, but the representation of a line. For however fine you may make these representations, they will still have some breadth. But by the definition, a line has no breadth whatever, yet it is impossible to draw any thing so fine as to have no breadth. A line therefore, can only be imagined. The ends of a line are points.

3. A *right line* is what is commonly called a *straight line*, or that tends every where the same way.

4. A *curve* is a line which continually changes its direction between its extreme points.

5. *Parallel* lines are such as always keep at the same distance from each other, and which, if prolonged ever so far, would never meet. *Fig.* 1.

6. An *angle* is the inclination or opening of two lines meeting in a point, *Fig.* 2.

7. The lines AB, and BC, which form the angle, are called the legs or sides; and the point B where they meet, is called the *vertex* of the angle, or the *angular point*. An angle is sometimes expressed by a letter placed at the vertex, as the angle B, *Fig.* 2; but most commonly by three letters, observing to place in the middle the letter at the vertex, and the other two at the end of each leg, as the angle ABC.

8. When one line stands upon another, so as not to lean more to one side than to another, both the angles which it makes with the other are called *right angles*, as the angles ABC and ABD, *Fig.* 3, and all right-angles are equal to each other, being all equal to 90°; and the line AB is said to be *perpendicular* to CD.

Beginners are very apt to confound the terms *perpendicular*, and *plumb* or *vertical line.* A line is vertical when it is at right-angles to the plane of the horizon, or level surface of the earth, or to the surface of water, which is always level. The sides of a house are vertical. But a line may be perpendicular to another, whether it stands upright or inclines to the ground, or even if it lies flat upon it, provided only that it makes the two angles formed by meeting with the other line equal to each other; as for instance, if the angles ABC and ABD be equal, the line AB is perpendicular to CD, whatever may be its position in other respects.

9. When one line, BE (*Fig.* 3,) stands upon another, CD, so as to incline, the angle EBC, which is greater than a right-angle, is called an *obtuse* angle; and that which is less than a right-angle, is called an *acute* angle, as the angle EBD.

10. Two angles which have one leg in common, as the angles ABC, and ABE, are called *contiguous* angles, or *adjoining* angles; those which are produced by the crossing of two lines, as the angles EBD and CBF, formed by CD and EF, crossing each other, are called *opposite* or *vertical* angles.

11. A *figure* is a bounded space, and is either a *surface* or a *solid.*

12. A *superficies,* or *surface,* has length and breadth only. The extremities of a superficies are lines.

13. A *plane,* or *plane surface,* is that which is every where perfectly flat and even, or which will touch every part of a straight line, in whatever direction it may be laid upon it. The top of a marble slab, for instance, is an example of this, which a strait edge will touch in every point, so that you cannot see light any where between.

14. A *curved surface* is that which will not coincide with a straight line in any part. Curved surfaces may be either convex or concave.

15. A *convex surface* is when the surface rises up in the middle, as, for instance, a part of the outside of a globe.

16. A *concave surface* is when it sinks in the middle, or is hollow, and is the contrary to convex.

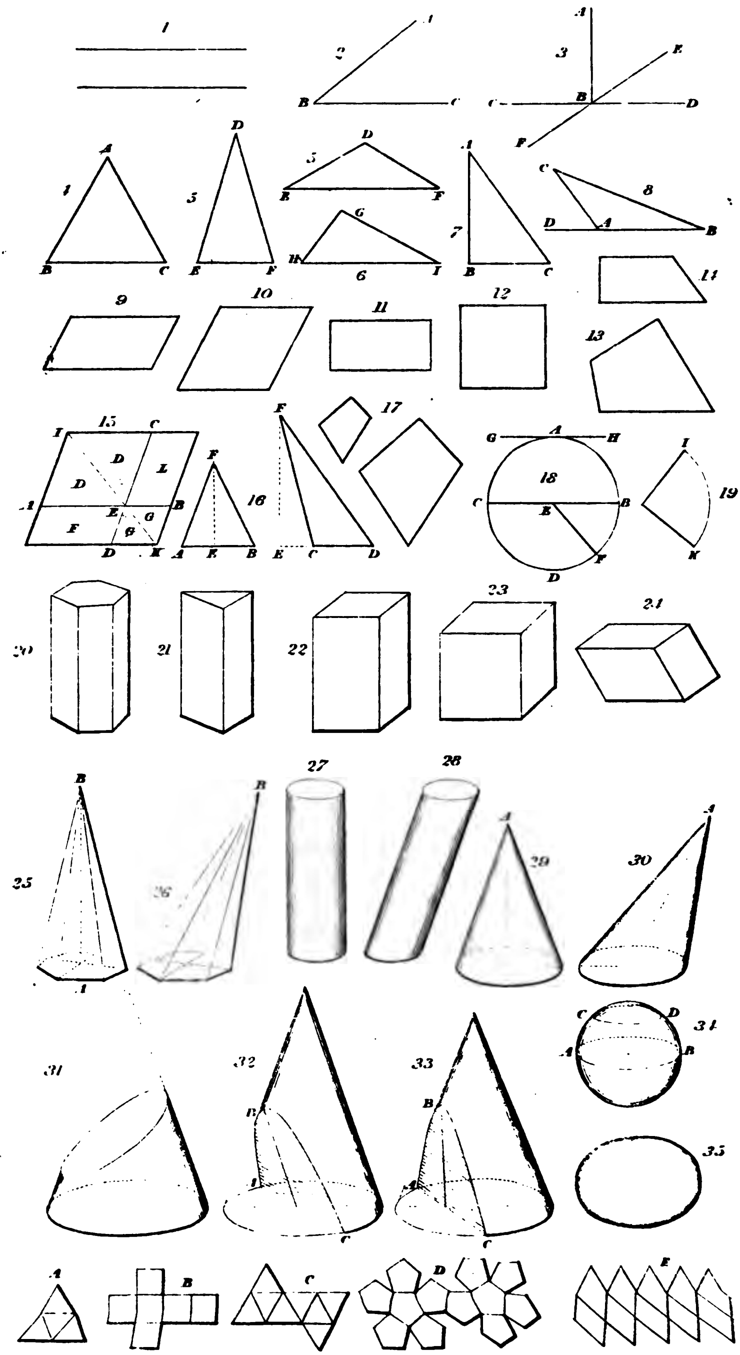
A surface may be bounded either by straight lines, curved lines, or both these.

17. Every surface, bounded by straight lines only, is called a *polygon.* If the sides are all equal, it is called a *regular polygon.* If they are unequal, it is called an *irregular polygon.* Every polygon, whether equal or unequal, has the same number of sides as angles, and they are denominated sometimes according to the number of sides, and sometimes from the number of angles they contain. Thus a figure of three sides is called a *triangle,* and a figure of four sides a *quadrangle.*

A *pentagon* is a polygon of five sides.,

GEOMETRY

Plate 89. *Definitions.* Page 674.



A *hexagon* has six sides.
A *heptagon* seven sides.
An *octagon* eight sides.
A *nonagon* nine sides.
A *decagon* ten sides.
An *undecagon* eleven sides.
A *duodecagon* twelve sides.

When they have a greater number of sides, it is usual to call them polygons of 13 sides, of 14 sides, and so on.

Triangles are of different kinds, according to the lengths of their sides.

18. An *equilateral triangle* has all its sides equal, as ABC, *Fig.* 4.

19. An *isosceles triangle* has two equal sides, as DEF, *Fig.* 5.

20. A *scalene triangle* has all its sides unequal, as GHI, *Fig.* 6.

Triangles are also denominated according to the angles they contain.

21. A *right-angled* triangle is one that has in it a right angle, as ABC, *Fig.* 7.

22. A triangle cannot have more than one right-angle. The side opposite to the right-angle B, as AC, is called the *hypothenuse*, and is always the longest side.

23. An *obtuse-angled* triangle has one obtuse-angle, as *Fig.* 8.

24. An *acute-angled* triangle has all its angles acute, as *Fig.* 4.

25. An isosceles, or a scalene triangle, may be either right-angled, obtuse, or acute.

26. Any side of a triangle is said to *subtend* the angle opposite to it: thus AB (*Fig.* 7), subtends the angle ACB.

27. If the side of a triangle be drawn out beyond the figure, as AD (*Fig.* 8), the angle A, or CAB, is called an *internal* angle, and the angle CAD, or that without the figure, an *external* angle.

28. A *quadrangle* is also called a *quadrilateral* figure. They are of various denominations, as their sides are equal or unequal, or as all their angles are right-angles or not.

29. Every four-sided figure whose opposite sides are parallel, is called a *parallelogram*. Provided that the sides opposite to each other be parallel, it is immaterial whether the angles are right or not. *Fig.* 9, 10, 11, and 12, are all parallelograms.

30. When the angles of a parallelogram are all right-angles, it is called a *rectangular parallelogram* or a *rectangle*, as *Fig.* 11 and 12.

31. A rectangle may have all its sides equal, or only the opposite sides equal. When all its sides are equal, it is called a *square*, as *Fig.* 12.

32. When the opposite sides are parallel, and all the sides equal to each other, but the angles not right-angles, the parallelogram is called a *rhombus*, as *Fig.* 10.

33. A parallelogram having all its angles oblique, and only its opposite equal, is called a *rhomboid*, as *Fig.* 9.

34. When a quadrilateral or four-sided figure has none of its sides parallel, it is called a *trapezium*, as *Fig.* 13; consequently every quadrangle, or quadrilateral which is not a parallelogram, is a trapezium.

35. A *trapezoid* has only one pair of its sides parallel, as *Fig.* 14.

36. A *diagonal* is a right line drawn between any two angles that are opposite in a polygon, as IK, *Fig.* 15. In parallelograms the diagonal is sometimes called the *diameter*, because it passes through the centre of the figure.

37. *Complements* of a parallelogram. If any point, as E (*Fig.* 15), be taken in the diagonal of a parallelogram, and through that point two lines are drawn parallel to the sides, as AB, CD, it will be divided into four parallelograms, DD, L, F, GG. The two divisions, L, F, through which the diameter does not pass, are called the complements.

38. *Base* of a figure is the side on which it is supposed to stand erect, as AB, and CD, *Fig.* 16.

39. *Altitude* of a figure is its perpendicular height from the base to the highest part, as EF, *Fig.* 16.

40. *Area* of a plane figure, or other surface, means the quantity of space contained within its boundaries, expressed in square feet, yards, or any other superficial measure.

41. *Similar figures* are such as have the same angles, and whose sides are in the same proportion, as *Fig.* 17.

42. *Equal* figures are such as have the same area or contents.

43. A *circle* is a plane figure, bounded by a curve line returning into itself, called its *circumference*, ABCD (*Fig.* 18), every where equally distant from a point E within the circle, which is called the *centre*.

44. The *radius* of a circle is a straight line drawn from the centre to the circumference, as EF (*Fig.* 18). The radius is the opening of the compass when a circle is described; and consequently all the radii of a circle must be equal to each other.

45. A *diameter* of a circle is a straight line drawn from one side of the circumference to the other through the centre, as CB (*Fig.* 18). Every diameter divides the circle into two equal parts.

46. A *segment* of a circle is a part of a circle cut off by a straight line drawn across it. This straight line is called the *chord*. A segment may be either equal to, greater, or less than a *semi-circle*, which is a segment formed by the diameter of the circle, as CEB, and is equal to half the circle.

47. A *tangent* is a straight line, drawn so as just to touch a circle without cutting it, as GH (*Fig.* 18). The point A, where it touches the circle, is called the *point of contact*. And a tangent cannot touch a circle in more points than one.

48. A *sector* of a circle is a space comprehended between two radii and an arc, as BIK (*Fig.* 19).

49. The circumference of every circle, whether great or small, is supposed to be divided into 360 equal parts, called *degrees*; and every degree into 60 parts, called minutes; and every minute into 60 seconds. To measure the inclination of lines to each other, or angles, a circle is described round the angular point, as a centre, as IK, *Fig.* 19; and according to the number of degrees, minutes, and

seconds, cut off by the sides of the angle, so many degrees, minutes, and seconds, it is said to contain. Degrees are marked by °, minutes by ′, and seconds by ″; thus an angle of 48 degrees, 15 minutes, and 7 seconds, is written in this manner, 48° 15′ 7″.

50. A *solid* is any body that has length, breadth, and thickness: a book, for instance, is solid, so is a sheet of paper; for though its thickness is very small, yet it has some thickness. The boundaries of a solid are *surfaces*.

51. *Similar solids* are such as are bounded by an equal number of similar planes.

52. A *prism* is a solid, of which the sides are parallelograms, and the two ends or bases are similar polygons, parallel to each other. Prisms are denominated according to the number of angles in the base, *triangular* prisms, *quadrangular, heptangular,* and so on, as *Fig.* 20, 21, 22, 23. If the sides are perpendicular to the plane of the base, it is called an *upright* prism; if they are inclined, it is called an *oblique* prism.

53. When the base of a prism is a parallelogram, it is called a *parallelopipedon,* as *Fig.* 22 and 23. Hence, a parallelopipedon is a solid, terminated by six parallelograms.

54. When all the sides of a parallelopipedon are squares, the solid is called a *cube,* as *Fig.* 23.

55. A *rhomboid* is an oblique prism, whose bases are parallelograms. (*Fig.* 24.)

56. A *pyramid* AB (*Fig.* 25 and 26) is a solid, bounded by, or contained within, a number of planes, whose base may be any polygon, and whose faces are triangles terminated in one point, B, commonly called the *summit,* or *vertex* of the pyramid.

57. When the figure of the base is a triangle, it is called a *triangular pyramid;* when the figure of the base is a quadrilateral, it is called a *quadrilateral pyramid,* &c.

58. A pyramid is either *regular* or *irregular,* according as the base is regular or irregular.

59. A pyramid is also *right* or *upright,* or it is *oblique.* It is right, when a line drawn from the vertex to the centre of the base, is perpendicular to it, as *Fig.* 25; and oblique, when this line inclines, as *Fig.* 26.

60. A *cylinder* is a solid (*Fig.* 27 and 28) generated or formed by the rotation of a rectangle about one of its sides, supposed to be at rest; this quiescent side is called the *axis* of the cylinder. Or it may be conceived to be generated by the motion of a circle, in a direction perpendicular to its surface, and always parallel to itself.

61. A cylinder is either *right* or *oblique,* as the axis is perpendicular to the base or inclined.

62. Every *section* of a right cylinder taken at right-angles to its axis, is a *circle;* and every section taken across the cylinder, but oblique to the axis, is an *ellipsis.*

63. A circle being a polygon of an infinite number of sides, it fol-

88. The *measure* or *quantity* of a ratio, is conceived by considering what part of the consequent is the antecedent; consequently, it is obtained by dividing the consequent by the antecedent.

89. *Three* magnitudes or quantities, A, B, C, are said to be *proportional,* when the ratio of the first to the second is the same as that of the second to the third. Thus, 2, 4, 8, are proportional, because 4 is contained in 8 as many times as 2 is in 4.

90. *Four* quantities, A, B, C, D, are said to be proportional, when the ratio of the first, A, to the second, B, is the same as the ratio of the third, C, to the fourth, D. It is usually written, A : B :: C : D, or, if expressed in numbers, 2 : 4 :: 8 : 16.

91. Of *three* proportional quantities, the middle one is said to be a *mean proportional* between the other two; and the last a *third proportional* to the first and second.

92. Of *four* proportional quantities, the last is said to be a *fourth proportional* to the other three, taken in order.

93. *Ratio of equality* is that which equal numbers bear to each other.

94. *Inverse ratio* is when the antecedent is made the consequent, and the consequent the antecedent. Thus, if 1 : 2 :: 3 : 6; then, *inversely*, 2 : 1 :: 6 : 3.

95. *Alternate proportion* is when the antecedent is compared with antecedent, and consequent with consequent. Thus, if 2 : 1 :: 6 : 3; then, by *alternation*, 2 : 6 :: 1 : 3.

96. Proportion by *composition* is when the antecedent and consequent, taken as one quantity, are compared either with the consequent or with the antecedent. Thus, if 2 : 1 :: 6 : 3; then, by *composition*, 2+1 : 1 :: 6+3 : 3, and 2+1 : 2 :: 6+3 : 6.

97. *Divided proportion* is when the difference of the antecedent and consequent is compared either with the consequent or with the antecedent. Thus, if 3 : 1 :: 12 : 4; then, by *division*, 3—1 : 1 :: 12—4 : 4, and 3—1 : 3 :: 12—4 : 12.

98. *Continued proportion* is when the first is to the second as the second to the third; as the third to the fourth; as the fourth to the fifth; and so on.

99. *Compound ratio* is formed by the multiplication of several antecedents and the several consequents of ratios together, in the following manner:

If A be to B as 3 to 5, B to C as 5 to 8, and C to D as 8 to 6; then A will be D, as $\frac{3\times5\times8}{5\times8\times6}=\frac{120}{240}=\frac{1}{2}$; that is, A : D :: 1 : 2.

100. *Bisect,* means to divide any thing into two equal parts.

101. *Trisect,* is to divide any thing into three equal parts.

102. *Inscribe,* to draw one figure within another, so that all the angles of the inner figure touch either the angles, sides, or planes of the external figure.

103. *Circumscribe,* to draw a figure round another, so that either the angles, sides, or planes of the circumscribed figure, touch all the angles of the figure within it.

104. *Rectangle under any two lines*, means a rectangle which has two of its sides equal to one of the lines, and two of them equal to the other. Also, the rectangle under AB, CD, means AB × CD.

105. *Scales of equal parts.* A scale of equal parts is only a straight line, divided into any number of equal parts, at pleasure. Each part may represent any measure you please, as an inch, a foot, a yard, &c. One of these is generally subdivided into parts of the next denomination, or into tenths or hundredths. Scales may be constructed in a variety of ways. The most usual manner is, to make an inch, or some aliquot part of an inch, to represent a foot; and then they are called inch scales, three-quarter inch scales, half-inch scales, quarter-inch scales, &c. They are usually drawn upon ivory or box-wood.

106. An *axiom* is a manifest truth, not requiring any demonstration.

107. *Postulates* are things required to be granted true, before we proceed to demonstrate a proposition.

108. A *proposition* is when something is either proposed to be done, or to be demonstrated, and is either a *problem* or a *theorem.*

109. A *problem* is when something is proposed to be done, as some figure to be drawn.

110. A *theorem* is when something is proposed to be demonstated or proved.

111. A *lemma* is when a premise is demonstrated, in order to render the thing in hand the more easy.

112. A *corollary* is an inference drawn from the demonstration of some proposition.

113. A *scholium* is when some remark or observation is made upon something mentioned before.

114. The sign = denotes that the quantities betwixt which it stands, are equal.

115. The sign + denotes that the quantity after it, is to be added to that immediately before it.

116. The sign — denotes, that the quantity after it is to be taken away or subtracted from the quantity preceding it.

Geometrical Problems.

Prob. 1. To divide a given line AB into two equal parts.

From the points A and B, as centres, and with any opening of the compasses greater than half AB, describe arches, cutting each other in c and d. Draw the line c d; and the point E, where it cuts A B, will be the middle required.

Prob. 2. To raise a perpendicular to a given line A B, from a point given at C.

Case 1. When tne given point is near the middle of the line, on each side of the point C. Take any two equal distances, C d and C e; from d and e, with any radius or opening of the compasses greater than C d or C e, describe two arcs cutting each other in f. Lastly, through the points f, C, draw the line f C, and it will be the perpendicular required.

Case 2. When the point is at, or near the end of the line. Take any point d, above the line, and with the radius or distance d C, describe the arc e C f, cutting AB in e and C. Through the centre d, and the point e, draw the line e d f, cutting the arc e C f in f. Through the points f C, draw the line fC, and it will be the perpendicular required.

Prob. 3. From a given point f, to let fall a perpendicular upon a given line AB.

From the point f, with any radius, describe the arc d e, cutting AB in e and d. From the points e d, with the same or any other radius, describe two arcs, cutting each other in g. Through the points f and g, draw the line f g, and f C will be the perpendicular required.

Prob. 4. To make an angle equal to another angle which is given, as a B b.

From the point B, with any radius, describe the arc a b, cutting the legs B a, B b, in the points a and b. Draw the line D e, and from the point D, with the same radius as before, describe the arc e f, cutting D e in e. Take the distance B a, and apply it to the arc e f, from e to f. Lastly, through the points D, f, draw the line D f, and the angle e D f will be equal to the angle b B a, as was required.

Prob. 5. To divide a given angle, ABC, into two equal angles.

From the point B, with any radius, describe the arc AC. From A and C, with the same, or any other radius, describe arcs cutting each in d. Draw the line B d, and it will bisect the angle ABC, as was required.

Prob. 6. To lay down an angle of any number of degrees.

There are various methods of doing this. One is by the use of an instrument called a *protractor*, with a semicircle of brass, having its circumference divided into degrees. Let AB be a given line, and let it be required to draw from the angular point A, a line making, with AB, any number of degrees, suppose 20. Lay the straight side of the protractor along the line AB, and count 20° from the end B of the semicircle; at C, which is 20° from B, mark; then, removing the protractor, draw the line AC, which makes, with AB, the angle required. Or, it may be done by a divided line, usually drawn upon scales, called a *line of chords.* Take 60° from the line of chords, in the compasses, and setting one at the angular point B, *Prob.* 4, with that opening as a radius, describe an arch, as a b: then take the number of degrees of which you intend the angle to be, and set it from b to a, then is a B b the angle required.

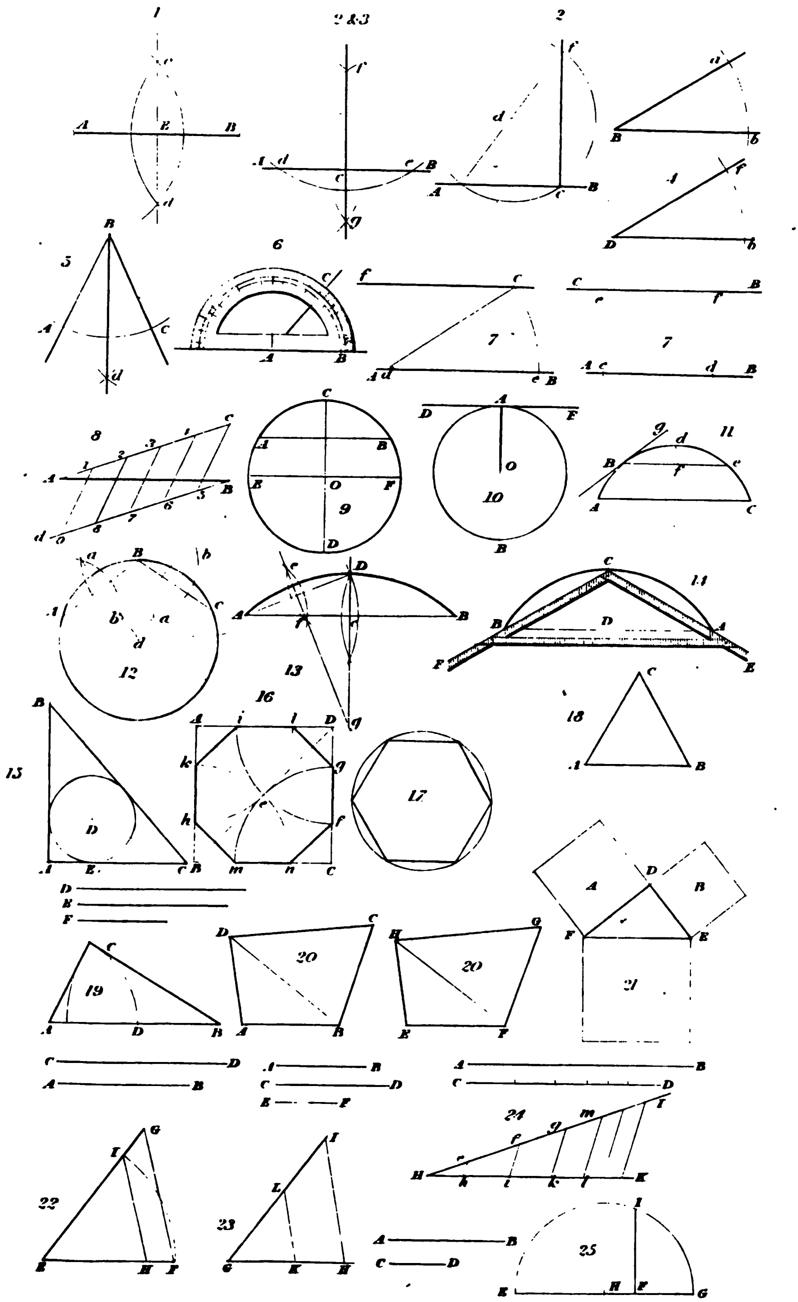
Prob. 7. Through a given point C, to draw a line parallel to a given line AB.

Case 1. Take any point d, in AB; upon d and C, with the distance C d, describe two arcs, e C, and d f, cutting the line AB in e and d. Make d f equal to e C; through C and f draw C f, and it will be the line required.

Case 2. When the parallel is to be at a given distance from AB. From any two points, c and d, in the line AB, with a radius equal to the given distance, describe the arcs e and f: draw the line CB to

GEOMETRY

Plate 90 _ *Problems* _ Page 682.



touch those arcs without cutting them, and it will be parallel to AB, as was required.

Prob. 8. To divide a given line AB, into any proposed number of equal parts.

From A, one end of the line, draw A c, making any angle with AB; and from B, the other end, draw B d, making the angle A B d equal to B A c. In each of these lines, A c, B d, beginning at A and B, set off as many equal parts, of any length, as AB is to be divided into. Join the points C 5, 46, 57, and AB will be divided as required.

Prob. 9. To find the centre of a given circle, or of any one already described. Draw any chord AB, and bisect it with the perpendicular CD. Bisect CD with the diameter EF, and the intersection O will be the centre required.

Prob. 10. To draw a tangent to a given circle that shall pass through a given point, A.

From the centre O, draw the radius OA. Through the point A, draw DE perpendicular to OA, and it will be the tangent required.

Prob. 11. To draw a tangent to a circle, or any segment of a circle ABC, through a given point B, without making use of the centre of the circle.

Take any two equal divisions upon the circle, from the given point B, towards d and e, and draw the chord e B. Upon B, as a centre, with the distance B d, describe the arc f d g, cutting the chord e B in f. Make d g equal to d f; through g draw g B, and it will be the tangent required.

Prob. 12. Given three points, A, B, C, not in a straight line, to describe a circle that shall pass through them.

Bisect the lines AB, BC, by the perpendiculars a b, b d, meeting at d. Upon d, with the distance d A, d B, or d C, describe ABC, and it will be the required circle.

Prob. 13. To describe the segment of a circle to any length AB, and height CD.

Bisect AB by the perpendicular D g, cutting AB in c. From c make c D, on the perpendicular, equal to CD. Draw AD, and bisect it by a perpendicular e f, cutting D g in g. Upon g the centre, describe ADB, and it will be the required segment.

Prob. 14. To describe the segment of a circle by means of two rules, to any length AB, and perpendicular height CD in the middle of AB, without making use of the centre.

Place the rules to the height at C; bring the edges close to A and B; fix them together at C, and put another piece across them to keep them fast. Put in pins at A and B, then move the rulers round these pins, holding a pencil at the angular point C, which will describe the segment.

Prob. 15. In any given triangle to inscribe a circle.

Bisect any two angles A and C, with the lines AD and DB. From D, the point of intersection, let fall the perpendicular DE; it will be the radius of the circle required.

Prob. 16. In a given square, to describe a regular octagon.

Draw the diagonals AC and BD, intersecting at e. Upon the points A, B, C, D, as centres, with a radius e C, describe the arcs h e l, k e n, m e g, f e i. Join f n, m h, k i, l g, and it will be the required octagon,

Prob. 17. In a given circle, to describe any regular polygon.

Divide the circumference into as many parts as there are sides in the polygon to be drawn, and join the points of division.

Prob. 18. Upon a given line AB, to construct an equilateral triangle.

Upon the points A and B, with a radius equal to AB, describe arches cutting each other at C. Draw AC and BC, and ABC will be the triangle required.

Prob. 19. To make a triangle, whose sides shall be equal to three given lines D, E, F, any two of them being greater than the third.

Draw AB equal to the line D. Upon A, with the radius F, describe an arc CD. Upon B, with the radius E, describe another arc intersecting the former at C. Draw AC and CB, and ABC will be the triangle required.

Prob. 20. To make a trapezium equal and similar to a given trapezium ABCD.

Divide the given trapezium ABCD into two triangles, by the diagonal DB. Make EF equal to AB; upon EF construct the triangle EFH, whose sides shall be respectively equal to those of the triangle ABD, by the last problem. Upon HF, which is equal to DB, construct the triangle HFG, whose sides are respectively equal to DBC; then EFGH will be the trapezium required.

By the help of this problem, any plan may be copied; as every figure, however irregular, may be divided into triangles. Upon this the practice of land-surveying and making plans of estates, is founded.

Prob. 21. To make a square equal to two given squares. Make the sides DE and DF of the two given squares A and B, form the sides of a right-angled triangle FDE; draw the hypothenuse FE; on it describe the square EFGH; and it will be the square required.

Prob. 22. Two right lines AB, CD, being given, to find a third proportional. Make an angle HEI at pleasure; from E make EF equal to AB, and EG equal to CD: join FG. Make EI equal to EF, and draw HI parallel to FG; then EH will be the third proportional required; that is, EF : EG : : EH : EI, or AB : CD : : CD : EI.

Prob. 23. Three lines being given, to find a fourth proportional. Make the angle HGI at pleasure; from G make GH equal to AB, GI equal to CD, and join HI. Make GK equal to EF; draw KL through K, parallel to HI; then GL will be the fourth proportional required, that is, GH : GI : : GK : GL, or AB : CD : : EF : GL.

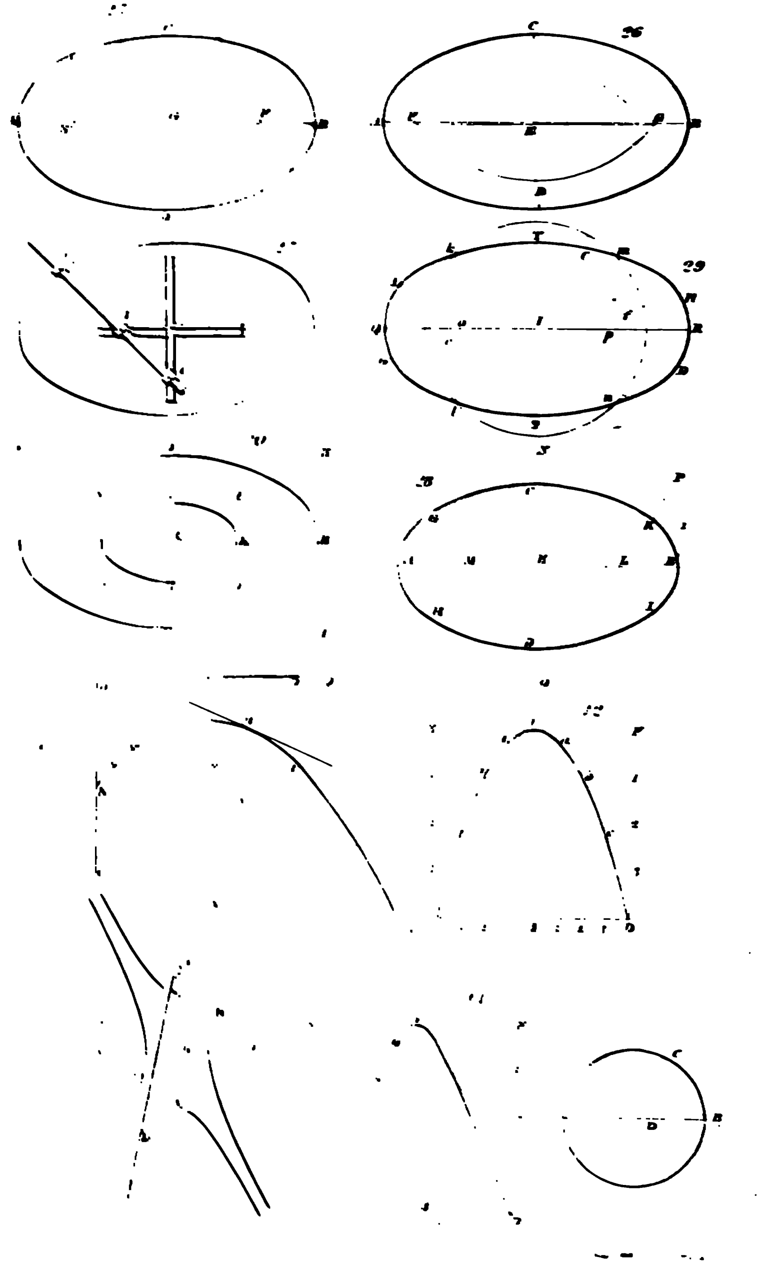
Prob. 24. To divide a given line AB in the same proportion as another CD is divided.

Make any angle KHI, and make HI equal to AB; then apply the

GEOMETRY

Problems

Plate 91. — Page 685.



several divisions of CD, from H to K, and join KI. Draw the lines h e, i f, k g, parallel to IK; and the line HI will be divided in e, f, g, as was required.

Prob. 25. Between two given lines AB and CD to find a mean proportional.

Draw the right line EG, in which make EF equal to AB, and FG equal to CD. Bisect EG in H, and with HE or HG, as radius, describe the semicircle EIG. From F draw FI perpendicular to EG, cutting the circle in I; and IF will be the mean proportional required.

Prob. 26. To describe an ellipsis.

If two pins are fixed at the points E and F, a string being put about them, and the ends tied together at C; the point C being moved round, keeping the string stretched will describe an ellipsis.

The points E and F, where the pins were fixed, are called the *foci.*

The line AB passing through the foci, is called the *transverse axis.*

The point G bisecting the transverse axis, is the *centre* of the ellipsis.

The line CD crossing this centre at right-angles to the transverse axis, is the *conjugate axis.*

The *latus rectum* is a right line passing through the focus at F, at right-angles to the transverse axis terminated by the curve: this is also called the *parameter.*

A *diameter* is any line passing through the centre, and terminated by the curve.

A *conjugate diameter* to another diameter, is a line drawn through the centre, parallel to a tangent at the extreme of the other diameter, and terminated by the curve.

A *double ordinate* is a line drawn through any diameter parallel to a tangent, at the extreme of that diameter terminated by the curve.

Prob. 26. The transverse axis AB, and conjugate axis CD, of any ellipsis, being given, to find the two foci, and from thence to describe the ellipsis.

Take the semi-transverse AE, or EB, and from C as a centre, describe an arc, cutting AB at F and G, which are the foci. Fix pins in these points; a string being stretched about the joints FCG, the ellipsis is described as above.

Prob. 27. The same being given, to describe an ellipsis by a *trammel.*

The trammel is an instrument consisting of two rulers fixed at right-angles to each other, with a groove in each. A rod with two moveable nuts works in this groove, and, by means of a pencil fixed in the end of the rod, describes the curve. The operation is as follows:

Let the distance of the first pin at B, from the pencil at A, be equal to half the shortest axis, and the distance of the second pin at C, from A, to half the longest axis; the pins being put in the grooves, move the pencil at A, which will describe the ellipsis.

Prob. 28. To draw the representation of an ellipsis with a compass to any length AB, and width CD.

Draw BP parallel and equal to EC, and bisect it at 1; then draw

I C and PD, cutting each other at K; bisect KC by a perpendicular meeting CD in O; and on O, with the radius OC, describe the quadrant CGQ.

Through Q and A, draw QG, cutting the quadrant at G; then draw GO, cutting AB at M; make EL equal to EM, also EN equal to EO. From N, through M and L draw NH and NI; then M, L, N, O, are the four centres by which the four quarters of the ellipsis are drawn.

It must be observed, that this is not a true ellipsis, but only an approximation to it; for it is impossible to draw a perfect ellipsis by means of compasses, which can only describe parts of circles. But the curve of an ellipsis differs essentially from that of a circle in every part; and no portions of circles put together, can ever form an ellipsis. But by this means, a figure may be drawn, which approaches nearly to an ellipsis, and therefore may be often substituted for it when a trammel cannot be had, or when the ellipsis is too small to be drawn by it. At the joining of the portions of circles in this operation, the defect is not perceivable; and the best way is not to join them quite, and to help the curve by hand.

Prob. 29. An ellipsis, ACDB, being given, to find the transverse and conjugate axis.

Draw any two parallel lines, AB and CD, cutting the ellipsis at the points A, B, C, D; bisect them in e and f. Through e and f, draw GH, cutting the ellipsis at G and H; bisect GH at I; and it will give the centre.

Upon I, with any radius, describe a circle, cutting the ellipsis in the four points k, l, m, n; join k, l, and m, n; bisect k l, or m n, at o or p. Through the points o, I, or I, p, draw QR, cutting the ellipsis at Q and R; then QR will be the transverse axis. Through I draw TS, parallel to k l, cutting the ellipsis at T and S; and TS will be the conjugate axis.

Prob. 30. To describe an ellipsis similar to a given one ADBC, to any given length IK, or to a given width ML.

Let AB and CD be the two axes of the given ellipsis. Through the points of contact A,D,B,C, complete the rectangle GEHF; draw the diagonals EF and GH: they will pass through the centre at R. Through I and K draw PN and OQ parallel to CD, cutting the diagonals EF and GH, at P,N,Q,O. Join PO and NQ, cutting CD at L and M; then IK is the transverse, and ML the conjugate axis of an ellipsis, that will be similar to the given ellipsis ADBC, which may be described by some of the foregoing methods.

Prob. 31. To describe a parabola. If a thread equal in length to BC, be fixt at C, the end of a square ABC, and the other end be fixt at F; and if the side AB of the square be moved along the line AD, and if the point E be always kept close to the edge BC of the square, keeping the string tight, the point or pin E will describe a curve EGIH, called a *parabola*.

The *focus* of the parabola is the fixed point F, about which the [illegible]

The *directrix* is the line AD, which the side of the square moves along.

The *axis* is the line LK, drawn through the focus F, perpendicular to the directrix.

The *vertex* is the point I, where the line LK cuts the curve.

The *latus rectum*, or *parameter*, is the line GH passing through the focus F, at right-angles to the axis IK, and terminated by the curve.

The *diameter* is any line MN, drawn parallel to the axis IK.

A *double ordinate* is a right line RS, drawn parallel to a tangent at M, the extreme of the diameter MN, terminated by the curve.

The *abscissa* is that part of a diameter contained between the curve and its ordinate, as MN.

Prob. 32. To describe a *parabola*, by finding points in the curve; the axis AB, or any diameter being given, and a double ordinate CD.

Through A draw EF parallel to CD; through C and D draw DF and CE parallel to AB, cutting EF at E and F. Divide BC and BD, each into any number of equal parts, as four; likewise divide CE and DF into the same number of equal parts. Through the points 1, 2, 3, &c. in CD, draw the lines 1 a, 2 b, 3 c, &c. parallel to CD; also through the points 1, 2, 3, in CE and DF, draw the lines 1 A, 2 A, 3 A, cutting the parallel lines at the points a, b, c · then the points a, b, c, are in the curve of the parabola.

Prob. 33. To describe an *hyperbola*.

If B and C are two fixed points, and a rule AB be made moveable about the point B, a string ADC being tied to the other end of the rule, and to the point C; and if the point A be moved round the centre B, towards G, the angle D of the string ADC, by keeping it always tight and close to the edge of the rule AB, will describe a curve DHG, called an hyperbola.

If the end of the rule at B were made moveable about the point C, the string being tied from the end of the rule A to B, and a curve being described after the same manner, is called an *opposite hyperbola*.

The *foci* are the two points B and C, about which the rule and string revolves.

The *transverse axis* is the line IH terminated by the two curves passing through the foci, if continued.

The *centre* is the point M, in the middle of the transverse axis IH.

The *conjugate axis* is the line NO, passing through the centre M, and terminated by a circle from H, whose radius is MC, at N and O.

A *diameter* is any line VW, drawn through the centre M, and terminated by the opposite curves.

Conjugate diameter to another, is a line drawn through the centre, parallel to a tangent with either of the curves, at the extreme of the other diameter terminated by the curves.

Abscissa is when any diameter is continued within the curve, terminated by a double ordinate and the curve; then the part within is called the abscissa.

Double ordinate is a line drawn through any diameter parallel to its conjugate, and terminated by the curve.

Parameter or *latus rectum,* is a line drawn through the focus, perpendicular to the transverse axis, and terminated by the curve.

Prob. 34. To describe an hyperbola by finding points in the curve, having the diameter or axis AB, its abscissa BG, and double ordinate DC.

Through G draw EF, parallel to CD; from C and D draw CE and DF, parallel to BG, cutting EF in E and F. Divide CD and BD, each into any number of equal parts, as four; through the points of division, 1, 2, 3, draw lines to A. Likewise divide EC and DF into the same number of equal parts, viz. four; from the divisions on CE and DF, draw lines to G; a curve being drawn through the intersections at G, a, b, &c. will be the hyperbola required.

Remarks.—In a circle, the half chord DC, is a mean proportional between the segments AD, DB of the diameter AB perpendicular to it. That is AD : DC : : DC : DB.

2. The chord AC is a mean proportional between AD and the diameter AB. And the chord BC a mean proportional between DB and AB.

That is, AD : AC : : AC : AB,
and BD : BC : : BC : AB.

3 The angle ACB, in a semicircle, is always a right.

4. The square of the hypotenuse of a right-angled triangle, is equal to the squares of both the sides.

That is, $AC^2 = AD^2 + DC^2$,
and $BC^2 = BD^2 + DC^2$,
and $AB^2 = AC^2 + BC^2$.

5. Triangles that have all the three angles of the one respectively equal to all the three of the other, are called equiangular triangles, or similar triangles.

6. In similar triangles, the like sides, or sides opposite the equal angles, are proportional.

7. The areas, or spaces, of similar triangles, are to each other, as the squares of their like sides.

MENSURATION OF SUPERFICIES.

Prob. 1. To find the area of a parallelogram: whether it be a square, a rectangle, a rhombus, or a rhomboid.

Multiply the length by the breadth, or perpendicular height, and the product will be the area.

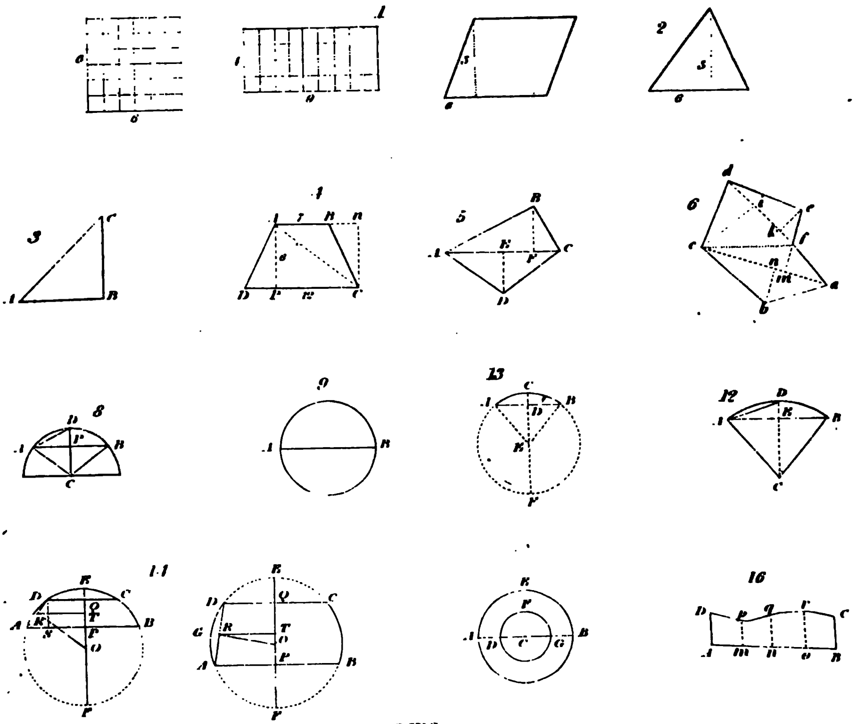
Ex. 1. To find the area of a square, whose side is 6 inches, or 6 feet, &c.

$$\begin{array}{r} 6 \\ 6 \\ \hline 36 \end{array} \text{ Ansr}$$

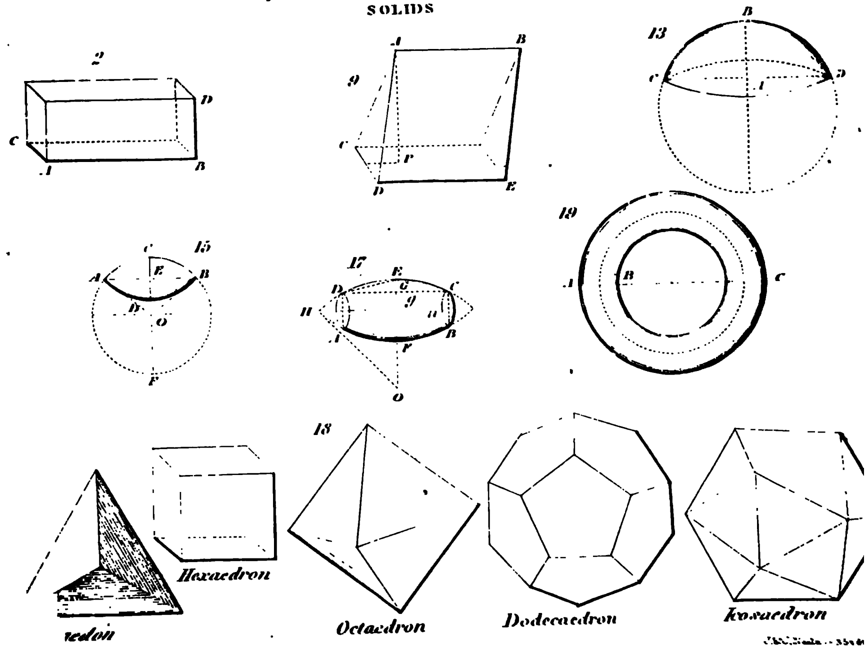
MENSURATION

Superficies

Plate 92. — Page 689.



SOLIDS



2. To find the area of a rectangle, whose length is 9, and breadth 4 inches, or feet, &c.

$$\begin{array}{r} 9 \\ 4 \\ \hline \text{Ansr. } 36 \\ \hline \end{array}$$

3. To find the area of a rhombus, whose length is 6 chains, and perpendicular height 5.

$$\begin{array}{r} 6 \\ 5 \\ \hline \text{Ansr. } 30 \\ \hline \end{array}$$

Prob. 2. To find the Area of a Triangle.

Rule 1. Multiply the base by the perpendicular height, and half the product will be the area.

Rule 2. When the three sides only are given : Add the three sides together, and take half the sum ; from the half sum subtract each side separately ; multiply the half sum and the three remainders continually together ; and the square root of the last product will be the area of the triangle.

Ex. Required the area of the triangle whose base is 6 feet, and perpendicular height 5 feet.

$$\begin{array}{r} 6 \\ 5 \\ \hline 2)\ 30\ (15 \text{ Ansr.} \end{array}$$

Prob. 3. To find one Side of a right-angled Triangle, having the other two Sides given.

The square of the hypotenuse is equal to both the squares of the two legs. Therefore,

1. To find the hypotenuse ; add the squares of the two legs together, and extract the square root of the sum.

2. To find one leg ; subtract the square of the other leg from the square of the hypotenuse, and extract the root of the difference.

Ex. 1. Required the hypotenuse of a right-angled triangle, whose base A B is 40, and perpendicular BC 30.

$$\begin{array}{rr} 4 & 3 \\ 4 & 3 \\ \hline 16 & 9 \\ 9 & \\ \hline 25 & \\ 25 & \\ \hline \end{array}$$

(5 the square root of the sum of the two squares, being the hypotenuse AC.

2. What is the perpendicular of a right-angled triangle, whose base AB is 56, and hypotenuse, AC 65?

```
 56    65
 56    65
----  ----
 336   325
280   390
----  ----
3136  4225
      3136
      ----
      1089 ( 33 The perpendicular, which is the root
       9         of the remainder of the square of the
   --------      hypotenuse AC, when the square
  63 | 189       of AB has been subtracted.
   3 | 189
```

Prob. 4. To find the Area of a Trapezoid.

Multiply the sum of the two parallel sides by the perpendicular distance between them, and half the product will be the area.

Ex. In a trapezoid, the parallel sides are AB 7, and CD 12, and the perpendicular distance AP or CN is 9 : required the area.

```
  7
 12
---
 19
  9
---
171
---
85½ the area.
```

Prob. 5. To find the Area of a Trapezium.

Case for any trapezium.—Divide it into two triangles by a diagonal; then find the areas of these triangles, and add them together.

Note. If two perpendiculars be let fall on the diagonal, from the other two opposite angles, the sum of these perpendiculars being multiplied by the diagonal, half the product will be the area of the trapezium.

Ex. To find the area of the trapezium ABCD, the diagonal AC being 42, the perpendicular BF 18, and the perpendicular DE 16.

```
     18
     16
    ---
     34
     42
    ---
     68
    136
2 ) 1428
   -----
    714 the answer.
```

Prob. 6. To find the Area of an Irregular Polygon.

Draw diagonals dividing the figure into trapeziums and triangles. Then find the areas of all these separately, and their sum will be the content of the whole irregular figure.

Ex. To find the content of the irregular figure ABCDEF, in which are given the following diagonals and perpendiculars : namely,

c.a = 10
d.f = 6
c.i = 4
k.e = 2
m.f = 3
n.b = 4

For trapez. d c f e.		For trapez. c f a b	
ci.	4	n.b.	4
ke.	2	m.f.	3
	6		7
df.	6	c.a.	10
	2) 36		2) 70
	18 contents.		35 contents.

18 contents d. c. f e
35 —— c. f. a b

53 contents of the irregular polygon.

Prob. 7. To find the Area of a Regular Polygon.

Rule. Multiply the perimeter of the figure, or sum of its sides, by the perpendicular falling from its centre upon one of its sides, and half the product will be the area.

Prob. 8. In a Circular Arc, having any two of the following lines, viz. the chord AB, the versed sine DP, the chord of half the arc AD, and the diameter, or the radius AC or CD given, to find the others.

If any two of these lines be given, two sides of one of the right-angled triangles, APC or APD, will be known, and from them the remaining side, and other lines in the arc, may be found by Prob. 3.

Suppose AB and PD be given, then, by Prob. 3., the half of AB, or AP is a mean proportional between DP and PC + CD ; for PC + CD + PD is the diameter of the circle, half of which is the radius or CA, and by Prob. 3, $AC^2 - AP^2 = CP^2$, and $AP^2 + PD^2 = AD^2$.

Suppose CD and AB be given, then half of AB = AP, and CD = AC ; therefore $\sqrt{CD^2 - AP^2} = CP$, and $CD - CP = PD$. $\sqrt{PD^2 + AP^2} = AD$.

Prob. 9. To find the Diameter and Circumference of a Circle, the one from the other.

Rule 1. As 7 is to 22, so is the diameter to the circumference.
As 22 is to 7, so is the circumference to the diameter.

Rule 2. As 113 is to 355, so is the diameter to the circumference
As 355 is to 113, so is the circumference to the diameter

Rule 3. As 1 is to 3·1416, so is the diameter to the circumference.
As 3·1416 is to 1, so is the circumference to the diameter.

Ex. 1. To find the circumference of a circle, whose diameter AB is 10.

By Rule 1.

7 : 22 : : 10 : 31·42857
10

7) 220
$31\frac{3}{7}$
or 31·42857 ans.

By Rule 2.

113 : 355 : : 10 : $31\frac{47}{113}$
10

113) 3550 (31·41593 the ans.
160
470
180
670
1050
330

By Rule 3.

1 : 3·1416 : : 10 : 31·416 the circumference nearly, the true circumference being 31·415926535S979, &c.

So that the 2d rule is nearest the truth.

2. To find the diameter when the circumference is 100.

By Rule 1.

$$22 : 7 : : 50 : \frac{7 \times 25}{11} = \frac{175}{11} = 15\tfrac{10}{11} = 15{\cdot}\dot{9}\dot{0}90 \text{ ans}$$

By Rule 2.

355 : 113 : : 50 : 15$\frac{65}{71}$

```
          50
         ----
355 | 5650
    | ----
 71 | 1130 (15·9155
      ----
       420
       ----
        650
        ----
         110
         ----
          390
          ----
           350
           ----
```

By Rule 3

3·1416 : 1 : : 50 : 15·9156

```
              50
             ----
3·1416)50·000 (15·9156
             ------
   . ....) 18584
           -----
            2876
            ----
              49
              --
              18
              --
               2
              --
```

Prob. 10. To find the Length of any Arc of a Circle.

Rule 1. As 180 is to the number of degrees in the arc,
So is 3·1416 times the radius, to its length.
Or as 3 is to the number of degrees in the arc,
So is ·05236 times the radius, to its length.

Ex. 1. To find the length of an arc ADB (Prob. 8,) of 30 degrees, the radius being 9 feet.

```
                 3·1416
                      9
As 180 : 30      ------
Or 6 : 1 : : 282744 : 4·7124
Or 3 : 30 : : ·05236 × 9 : 4·7124
                     90
                 ------
                 4·7124 the answer.
                 ------
```

Rule 2. From 8 times the chord of half the arc subtract the chord of the whole arc, and $\frac{1}{3}$ of the remainder will be the length of the arc nearly.

Ex. 2. The chord AB (*Prob.* 8.) of the whole arc being 4·65874, and the chord AD of the half arc 2·34947; required the length of the arc.

```
     2·34947
           8
    --------
    18·79576
     4·65874
    --------
3 ) 14·13702
    --------
     4·71234 answer.
```

Prob. 11. **To find the Area of a Circle, the diameter or circumference being given.**

Rule 1. Multiply half the circumference by half the diameter. Or, take $\frac{1}{4}$ of the product of the whole circumference and diameter.

Rule 2. Multiply the square of the diameter by ·7854.

Rule 3. Multiply the square of the circumference by ·07958.

Rule 4. As 14 is to 11, so is the square of the diameter to the area.

Rule 5. As 88 is to 7, so is the square of the circumference to the area.

Ex. To find the area of a circle whose diameter is 10, and circumference 314·159265

By Rule 1.

```
      31·4159265
              10
    ------------
    4)314·159265
    ------------
area  78·539816
```

By Rule 2.

```
     ·7854
       100
     -----
area 78·54
```

By Rule 4.

```
14 : 11 : : 100
             11   area
           ----
     14 | 1100 | 78·57
        |   98 |
           ----
            120
            112
           ----
             80
             70
           ----
            100
             98
           ----
              2
```

By Rule 3.

```
sq. circ. 986·96044
  invert.     85970
         ----------
            6908723
             888264
              49348
               7896
         ----------
           78·54231 area.
         ----------
```

By Rule 5.

```
          31·4159265 circum.
          562951413  invert.
          ----------
           94247779
            3141593
            1256637
              31416
              15708
               2827
                 63
                 19
                  2
          ----------
88 : 7 : : 986·96044
                   7
          ----------
     8 | 6908·72308
       | ----------
    11 |  863·59038
          ----------
           78·50821
```

Prob. 12. To find the Area of the Sector of a Circle.

Rule 1. Multiply the radius, or half the diameter, by half the arc of the sector, for the area. Or take $\frac{1}{4}$ of the product of the diameter and arc of the sector.

Note. The arc may be found by problem 10.

Rule 2. As 360 is to the degrees in the arc of the sector, so is the whole area of the circle, to the area of the sector.

Ex. What is the area of the sector CAB, the radius being 10, and the chord AB 16.

$100 = AC^2$
$64 = AE^2$

36 ($6 = CE$
$10 = CD$

$4 = DE$

$16 = DE^2$
$64 = AE^2$

80 ($8{\cdot}9442719 = AD$.
8

71·5541752
16

3) 55·5541752

2) 18·5180584 arc ADB

9·2590297 = half arc
10 = radius

92·590297 answer.

Prob. 13. To find the Area of a Segment of a Circle.

Rule. Find the area of the sector having the same arc with the segment, by the last problem.

Find the area of the triangle, formed by the chord of the segment and the two radii of the sector.

Then the sum of these two will be the answer when the segment is greater than a semicircle: but the difference will be the answer when it is less than a semicircle.

Ex. Required the area of the segment ACBD, its chord AB being 12, and the radius EA or CE 10.

	100 AE^2		
	36 AD^2		
	64 DE^2		
its root	8 DE		
from	10 CE		
	2 CD		
	4 CD^2		
	36 AD^2		
	40 chord AC^2	6	AD
		8	DE
its root	6·324555 chord AC		
	8	48	area of Δ EAB
	50·596440		
	12·		
	3)38·59644		
	2)12·86548 arc ACB		
	6·43274 $\frac{1}{2}$ arc		
	10 radius		
	64·3274 area of sect. EACB		
	48·0000 area of triangle EAB		
ans.	16·3274 area of segm. ACBA		

Prob. 14. To find the Area of a Circular Zone ADCBA.

Rule 1. Find the areas of the two segments AEB, DEC, and their difference will be the zone ADCB.

Rule 2. To the area of the trapezoid DQP add the area of the small segment ADR; and double the sum for the area of the zone ADCB.

Prob. 15. To find the Area of a Circular Ring, or Space included between two Concentric Circles.

The difference between the two circles will be the ring. Or, multiply the sum of the diameters by their difference, and multiply the product by ·7854 for the answer.

Ex. The diameters of the two concentric circles being AB 10

and DG 6, required the area of the ring contained between their circumferences AEBA, and BFGD.

	10	·7854
	6	64
sum	16	31416
dif.	4	47124
	64	50·2656 Ansr.

Prob. 16. To measure long Irregular Figures.

Take the breadth in several places at equal distances. Add all the breadths together, and divide the sum by the number of them, for the mean breadth; which multiply by the length for the area.

Ex. The breadths of an irregular figure, at five equi-distant places being AD 8·1, mP 7·4, nq 9·2, or 10·1, BC 8·6; and the length AB 39; required the area.

```
    8·1
    7·4
    9·2
   10·1
    8·6
   ----
5) 43·4
   ----
   8·68
     39
   ----
   7812
  2604
  ----
 338·52 Ansr.
```

MENSURATION OF SOLIDS.

Prob. 1. To find the Solidity of a Cube.

Cube one of its sides for the contents; that is, multiply the side by itself, and that product by the side again.

Ex. If the side of a cube be 24 inches, what is its solidity or contents?

```
   24
   24
  ---
   96
  48
  ---
  576
   24
 ----
 2304
1152
-----
13824 Ansr.
```

Prob. 2. To find the Solidity of a Parallelopipedon.

Multiply the length by the breadth, and the products by the depth or altitude.

Ex. Required the contents of the parallelopipedon whose length AB is 6, its breadth AC 2, and altitude BD 3.

```
 6
 2
--
12
 3
--
36 Ansr.
```

Prob. 3. To find the Solidity of any Prism.

Multiply the area of the base, or end, by the height, and it will give the contents.

Which rule will do, whether the prism be triangular or square, or pentagonal, &c. or round, as a cylinder.

Ex. What is the content of a triangular prism, whose length is 12, and each side of its equilateral base 8?

Area of base, $28 \times 12 = 336$ contents.

Prob. 4. To find the Convex Surface of a Cylinder.

Multiply the circumference by the height of the cylinder.

Prob. 5. To find the Convex Surface of a Right Cone.

Multiply the circumference of the base by the slant height, or length of the side, and half the product will be the surface.

Ex. If the diameter of the base be 5 feet, and the side of the cone 18, required the convex surface.

```
     3·1416
          5
    -------
    15·7080 circumf.
         18
    -------
     125664
     15708
    -------
2 )  282·744
    -------
     141·372 Ansr.
```

***Prob.* 6.** To find the Convex Surface of the Frustum of a Right Cone

Multiply the sum of the perimeters of the two ends by the slant height or side of the frustum, and half the product will be the surface.

Ex. If the circumferences of the two ends be 12·5 and 10·3, and the slant height 14, required the convex surface of the frustum.

	12·5
	10·3
	22·8
	14
	912
	228
2)	319·2
	159·6 Ansr.

Prob. 7. To find the Solidity of a Cone, or any Pyramid.

Multiply the area of the base by the perpendicular height of the area, and one-third of the product will be the contents.

Prob. 8. To find the Solidity of any Frustum of a Cone or Pyramid.

Rule. Add together the area of the base, the area of the upper surface, and the mean proportional between those areas; take one-third of this sum for the mean area, which multiplied by the height will give the contents.—Or, for a cone, take the square of each diameter of the base and upper surface, and the product of these two diameters multiplied together; add these three sums together, and multiply by ·2618 for the mean area, which multiply as before.

Or, if the circumferences be used in like manner, instead of their diameters, the multiplier will be ·02654.

Ex. What is the content of the frustum of a cone, whose height is 20 inches, and the diameters of its two ends 28 and 20 inches?

Area of base	615·79	28	28	20
Area of upper surface	314·16	28	20	20
Mean proportional	439·84			
		224	560	400
3)	1369·79	56	784	
			400	
	456·59	784		
	20		1744	
			2618	
	9131·80			
			13952	
			1744	
			10464	
			3488	
			456·5792	
			20	
			9131·5840 Ansr.	

Prob. 9. To find the Solidity of a Wedge.

To the length of the edge add twice the length of the back or base, and reserve the sum; multiply the height of the wedge by the breadth of the base; then multiply this product by the reserved sum, and one-sixth of the last product will be the contents.

Ex. What is the contents of a wedge, whose altitude AP is 14 inches, its edge AB 21 inches, and the length of its base DE 32 inches, and its breadth CD $4\frac{1}{2}$ inches?

```
21      14
32      4½
32      ——
——      56
85       7
——      ——
        63
        85
       ————
       315
      504
      ————
 6 | 5355
   |  892·5 Ansr.
```

Prob. 10. To find the Solidity of a Prismoid.

Definition.—A prismoid differs only from the frustum of a pyramid, in not having its opposite ends similar planes.

Rule. Add into one sum, the areas of the two ends and four times the middle section parallel to them, and one-sixth of that sum will be a mean area; and being multiplied by the height, will give the contents.

Note.—The length of the middle section is equal to half the sum of the lengths of the two ends; and its breadth is equal to half the sum of the breadths of the two ends.

Ex. What are the contents of a prismoid whose ends are rectangles, the length and breadth of the one being 14 and 12; and the corresponding sides of the other 6 and 4, the perpendicular height being $30\frac{1}{2}$?

```
 14       10      6
 12        8      4
————      ——     ——
168       80     24
————       4     ——
         ————
         320
         168
          24
         ————
  6 )    512
```

$85\frac{1}{3}$ mean area.
$30\frac{1}{2}$ height.

2560
$42\frac{2}{3}$

2602·6 Ansr.

Prob. 11. To find the Convex Surface of a Sphere or Globe.
Multiply its diameter by its circumference.

Note.—In like manner the convex surface of any zone or segment is found, by multiplying its height by the whole circumference of the sphere.

Ex. Required the convex superficies of a globe, whose diameter or axis is 24.

```
3·1416
    24 diam.
------
125664
62832
------
75·3984 circumf.
     24
-------
3015936
1507968
---------
1809·5616 Ansr.
```

Prob. 12. To find the Solidity of a Sphere or Globe.
Multiply the cube of the axis by ·5236.

Ex. What is the solidity of the sphere, whose axis is 12?

```
    12
    12
   ---
   144
    12
  ----
  1728
 ·5236
 -----
 10368
 5184
3456
8640
--------
904·7808 Ansr.
```

Prob. 13. To find the Solidity of a Spherical Segment.

To 3 times the square of the radius of its base add the square of its height; then multiply the sum by the height, and the product again by ·5236.

Ex. Required the contents of a spherical segment, its height AB being 4, and the radius of its base CD 8.

```
   8       4        ·5236
   8       4          832
  ---     ---      -------
  64      16        10472
   3     192       15708
 ----    ----     41888
 192     208      --------
 ----      4      435·6352 Ansr.
         ----     --------
          832
         ----
```

Prob. 14. To find the Solidity of a Spherical Zone or Frustum.

Add together the square of the radius of each end and $\frac{1}{3}$ of the square of their distance, or the height; then multiply the sum by the said height, and the product again by 1·5708.

Ex. What is the solid contents of a zone, whose greater diameter is 12, the less 8, and the height 10 inches?

```
  6       4          10
  6       4          10
 ---     ---        ----
 36      16      3 ) 100
 ---     36         -----
         33⅓         33⅓
        -----       -----
         85⅓
       1·5708
       -------
        78540
      125664
         5236
     ---------
     134·0416
           10
     ---------
     1340·416 Ansr.
```

Prob. 15. To find the Surface of a Circular Spindle.

Multiply the length AB of the spindle by the radius OC of the revolving arc. Multiply also the said arc ACB by the central distance OE, or distance between the centre of the spindle and centre of the revolving arc. Subtract the latter product from the former, and multiply the remainder by 6·2832, for the surface.

Note. The same rule will serve for any segment ~ perpendicular to the chord of the revolving arc, on

ticular length of the part, and the part of the arc which describes it, instead of the whole length and whole arc.

Ex. Required the surface of a circular spindle, whose length AB is 40, and its thickness CD 30 inches.

Here, by the remarks at pa. 688.

The chord AC $= \sqrt{AE^2 + CE^2} = \sqrt{20^2 + 15^2} = 25$,

and 2 CE : AC : : AC : CO $= \frac{25^2}{30} = 20\frac{5}{6}$,

hence OE = OC − CE $= 20\frac{5}{6} - 15 = 5\frac{5}{6}$.

Also, by problem 10, rule 2, pa. 693

$$\begin{array}{rl} & 25 \text{ AC} \\ & 8 \\ \hline & 200 \\ & 40 \text{ AB} \\ \hline 3\,) & 160 \\ & 53\frac{1}{3} \text{ arc ACB} \\ \hline \end{array}$$

Then, by our rule,

$$\begin{array}{rr} 20\frac{5}{6} & 53\frac{1}{3} \\ 40 & 5\frac{5}{6} \\ \hline 800 & 266\frac{2}{3} \\ 33\frac{1}{3} & 44\frac{4}{9} \\ \hline 833\frac{1}{3} & 311\frac{1}{9} \\ 311\frac{1}{9} & \\ \hline \end{array}$$

$522\frac{2}{9}$ or 522·2 or $\frac{4700}{9}$

$$\begin{array}{r} 6{\cdot}2832 \\ \hline 10444 \\ 156666 \\ 4177777 \\ 10444444 \\ 313333333 \\ \hline 3281{\cdot}22666 \\ \hline \end{array}$$

Or thus,

$$\begin{array}{rr} & 6{\cdot}2832 \\ & 4700 \\ \hline & 439824 \\ & 251328 \\ \hline 9\,) & 29531{\cdot}04 \\ \hline & 3281{\cdot}226 \text{ ans. nearly} \\ \hline \end{array}$$

***Prob.* 16. To find the Solidity of a Circular Spindle.**

Multiply the central distance OE by half the area of the revoling segment ACBEA. Subtract the product from $\frac{1}{3}$ of the cube of EA, half the length of the spindle. Then multiply the remainder by 12·5664, or 4 times 3·1416, for the whole contents

Ex. Required the contents of the circular spindle, whose length AB is 40, and middle diameter CD 30.

By the work of the last problem,

we have OE $= 6\frac{5}{6}$	20 half length
and arc AC $= 26\frac{2}{3}$	20
and rad. OC $= 20\frac{5}{6}$	400
$533\frac{1}{3}$	20
$22\frac{2}{9}$	3) 8000
Sector OACB $555\frac{5}{9}$	
AE $\times$ OE=OAB $116\frac{2}{3}$	$2666\frac{2}{3}$
	$1280\frac{2}{9}$
2) $438\frac{8}{9}$	
	$1386\frac{4}{9}$
$\frac{1}{2}$ seg. ACE $219\frac{4}{9}$	
OE $5\frac{5}{6}$	or 1386·44
	4665·21 mult. inver.
$1097\frac{2}{9}$	
183 nearly	138644
	27739
$1280\frac{2}{9}$	6932
	832
	83
	5
	17423·5 Ansr.

Prob. 17. To find the Solidity of the Middle Frustum or Zone of a Circular Spindle.

From the square of half the length of the whole spindle, take $\frac{1}{3}$ of the square of half the length of the middle frustum, and multiply the remainder by the said half length of the frustum.——Multiply the central distance by the revolving area, which generates the middle frustum.—Subtract this latter product from the former; and the remainder multiplied by 6·2832, or twice 3·1416, will give the contents.

Ex. Required the solidity of the frustum, whose length m n is 40 inches, also its greatest diameter EF is 32, and least diameter AD or BC 24.

Draw DG parallel to m n, then we have DG $= \frac{1}{2}$m n $= 20$,

and $EG = \frac{1}{2}EF - \frac{1}{2}AD = 4$,

chord $DE^2 = DG^2 + GE^2 = 416$,

and $DE^2 \div EG = \frac{416}{4} = 104$ the diameter of the generating circle.

or the radius $OE = 52$,

hence $OI = 52 - 16 = 36$ the central distance,

and $HI^2 = OH^2 - OI^2 = 52^2 - 36^2 = 1408$,

$\frac{1}{3}DG^2 = \frac{1}{3}$ of $400 =$ .. .. $133\frac{1}{3}$,

$1274\frac{2}{3}$

DG 20

$25493\frac{1}{3}$ 1st. prod.

$GE \div 2\,OE = \frac{4}{104} = \frac{1}{26} = {\cdot}03846$ a ver. sine

Its tab. segment ..	·00994
but 104^2 is ..	10816
area of seg. DECGD	107·51104
$mD \times mn = 12 \times 40$	480·
gener. area m DEC n	587·51104
OI	36
	21150·39744 2d product
	25493·33333 1st product
	4342·93589
	2382·6 mult. inv.
	260576
	8686
	3474
	130
	9
	27287·5 Ansr.

Prob. 18. To find the Superficies or Solidity of any Regular Body.

1. Multiply the tabular area (taken from the following table) by the square of the linear edge of the body for the superficies.

2. Multiply the tabular solidity by the cube of the linear edge, for the solid contents.

DIRECTIONS TO THE BINDER.

The Binder will notice that the Signatures of this Work run from 2 M to 2 Z.

Signature 2 T is a single leaf, and cuts off the Title half-sheet.

There is no Signature 2 U, (pages 643 to 672.)

The Plates are to be placed facing their respective pages, they are all paged accordingly.

The Plate of *Stair-cases, Hand-rails, &c.* may be placed facing the Title, by way of Frontispiece.

The Prospectus of Nicholson's Operative Mechanic and British Machinist, which follows this page, is not to be cancelled.

WATER. On Water Mills in general
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RENNIE ON THE STRENGTH OF MATERIALS
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Printing Presses and Machinery, &c.—*Pile Engines,* by Valone—by Bunce. File Cutting Machine. Ramsden's Dividing Machine—Lathes and Turning Apparatus—by Maudesley—by Smart, &c.
MANUFACTURE OF METALS. *Iron.* The Ore—Qualities—Furnaces—Roasting—Smelting—Blast, regular—Intermediate Cylinder — Water Regulator — Carron Works—Conversion of Pig Iron into Wrought—Shingling—Welding—Common Hardening—Case Hardening—Refining Furnaces—Puddling Furnace—Tilt Hammer—Forge Hammer—Re-manufacturing Iron—Tables of the Weight of Bars, &c.
Steel. Cementation—Converting Furnace—Blistered Steel — Silver Steel — Cast Steel— Tempering Steel——Hardening Steel, &c.
Wire. Rolling —Drawing—Draw-bench Draw-Plates—Annealing—M. M. Mouchel's Manufactory—Wollaston's Experiments, &c.
Lead. Smelting the Ore—Reverberatory Furnace—Qualities of the Ore—Extracting Silver—Pig Lead—Sheet Lead—Lead Pipes—Wilkinson's Patent—Plumbing—Tinning, &c.
MANUFACTURE OF FIBROUS MATERIALS—Paper— Cotton —Wool—Silk—Flax—Weaving—Hemp and Rope—Tempering, &c.
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